Nitrate and Nebraska's Small Community and Rural Domestic Water Supplies:

An Assessment of Problems, Needs, and Alternatives

UNITED STATES DEPARTMENT OF THE INTERIOR
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ABBREVIATIONS USED IN THIS REPORT

AO	Administrative order (issued by HHSS, requiring corrective action for contaminated drinking water or some other threat to public health)
BMP	Best management practices
CDC	Centers for Disease Control and Prevention
CPNRD	Central Platte Natural Resources District
DEQ	Nebraska Department of Environmental Quality
DWR	Nebraska Department of Water Resources
EPA	United States Environmental Protection Agency
GAO	United States General Accounting Office
GWR	Groundwater region
HHSS	Nebraska Health and Human Services System
MCL	Maximum contaminant level (national drinking-water standard set by EPA)
mg/L	Milligrams per liter (equivalent to ppm)
NASS	Nebraska Agricultural Statistics Service
NC	Noncommunity water-supply system
NNRC	Nebraska Natural Resources Commission
NPWSP	Nebraska Public Water Supply Program
NRD	Natural resources district
NRS	Nebraska Revised Statutes
NTNC	Nontransient noncommunity water-supply system
ppm	Parts per million (equivalent to mg/L)
SDWA	Safe Drinking Water Act
UNL	University of Nebraska–Lincoln
WHP	Wellhead protection program
WHPA	Wellhead protection program area

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EXECUTIVE SUMMARY

INTRODUCTION

The Problem

Nitrate nitrogen in groundwater has been found to be a problem in many parts of the United States, and this is especially true in Nebraska, where groundwater accounts for more than 80% of public water supply withdrawals and virtually all private rural domestic water supply. This report considers how small public water supplies are being affected by nitrate contamination, how various communities have addressed the problem, the cost and effectiveness of these solutions, and other options available for small water supply systems. The report also gives limited consideration to rural domestic supplies.

Nitrate nitrogen is known to cause a disease called methemoglobinemia (or "blue baby syndrome") in infants, which inhibits the blood's ability to carry oxygen. It also may be converted to various nitrosamines in the water, which have been found to cause cancer. Because of these health concerns, the U.S. Environmental Protection Agency (EPA) has set a maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) for nitrate nitrogen in drinking water (EPA 1995).

Recently, Gosselin et al. (1997) sampled 1,808 individual domestic wells statewide and found that 19% of them exceeded the MCL for nitrate, although percentages varied widely by region (3% to 39%). These findings were consistent with those of other recent studies (Exner and Spalding, 1990; Spalding, 1991), which also found high levels of nitrate nitrogen in groundwater in some parts of Nebraska. All of these studies, however, focused on private domestic wells. One of the aims of this Bureau of Reclamation/Natural Resources Commission study is to analyze existing data from small community water supply systems and characterize how nitrate contamination has affected those systems.

The role of human activity in introducing nitrate into the environment is significant. Fertilizers, animal waste, waste lagoon sludge, septic systems, and nitrogen-bearing minerals in the soil have been cited as possible sources of contamination in past studies. Fertilizer use in Nebraska more than quadrupled between the early 1960's and the late 1970's but has not risen greatly since that time. Similarly, cattle numbers increased about 65% between 1950 and 1970 but were still near 1970 levels in 1996. Hog and pig numbers increased 64% from 1950 to 1980, and were still near the 1980 levels in 1996 (although they have dropped significantly since then). Estimates of the number of septic tanks vary widely, from a 1990 Census figure of 117,460 to other estimates as high as 250,000. The increases in fertilizer use, livestock populations, and numbers of septic tanks do not necessarily indicate a growing nitrate problem, since improvements in technology and management practices can decrease the potential for contamination. However, there is cause for concern that human activities may contribute to the increased levels of nitrate nitrogen.

Purpose of This Study

The purpose of this study was to investigate how nitrate contamination problems affect Nebraska's small community and rural domestic water supplies, analyze trends, and identify possible alternatives for meeting future needs. The study had four principal objectives:

1. Evaluate nitrate contamination conditions and trends in Nebraska, including available small community water supply nitrate testing records,
2. Examine nitrate-related infrastructure problems and needs of small community water systems,
3. Explore alternatives for addressing community water supply problems related to nitrate, and
4. Indicate potential courses of action.

Existing Information on Nitrate Conditions and Trends

Many reports have noted that a certain amount of nitrate occurs naturally in groundwater. Bachman (1984) suggested that natural background nitrate-nitrogen values rarely exceed 3 mg/L. Those wells with values greater than 3 mg/L are considered to have been affected by human activity.

A number of studies have been conducted to assess existing nitrate conditions for Nebraska's groundwater. The statewide assessment by Exner and Spalding (1990) concluded that nitrate-nitrogen concentrations exceed the MCL of 10 mg/L in groundwater beneath several areas of Nebraska, generally coinciding with irrigated croplands. These include, especially, the central Platte Valley and an area north of the Elkhorn River in Holt County. The most vulnerable areas are places where irrigated crop production occurs on well-drained soils with less than 50 feet to the water table. Nearly all of these areas are used for corn production with little crop rotation. Data compiled by Exner and Spalding (1990) indicated that both the magnitude and the areal extent of the contamination are increasing.

An earlier assessment by the Nebraska Department of Health (Hammer, 1980) tested 451 community water systems and found that 18 of them exceeded the MCL for nitrate. The three best options at that time, according to Hammer (1980) were to (1) protect the aquifer being used as a source of drinking water by discontinuing all other uses, (2) reserve a deeper, semiconfined aquifer for municipal use by excluding penetration of irrigation wells, and (3), if neither of these options were feasible, restrict fertilization and irrigation in the recharge zone surrounding community wells.

Probably the best assessment of existing domestic rural water quality was presented by Gosselin et al. (1996; summarized in Gosselin et al., 1997). These authors compiled and analyzed (1) water quality data from 1,808 individual domestic wells and (2) well-construction data collected as part of two statewide assessments—from 1985 to 1989 and from 1994 to 1995. Then they separated these data into those representing 13 groundwater regions (GWRs) and evaluated them by region. (See figure 2 for the distribution of GWRs.) They found that domestic, rural water quality varies substantially between groundwater regions as a function of well characteristics, distances to potential contamination sources, and hydrogeologic characteristics. Statewide, 19 percent of sampled wells had nitrate concentrations that exceeded the 10 mg/L MCL, but this percentage ranged from 3 to 39 percent among the individual groundwater regions. In comparing their results to the earlier statewide assessment (Spalding, 1991), Gosselin et al. noted that the degree of nitrate contamination had increased slightly in some regions (specifically, regions 1, 4, 5, 8, 9, and 13) while remaining generally unchanged in others (2, 6, 7, 10, 11, and 12). Overall, the median nitrate value in the sampled wells rose from 2.5 to 2.7 mg/L between one assessment and the next.

In a separate study, the Centers for Disease Control surveyed 583 domestic wells in Nebraska in 1994 and found that 14.7 percent of them had nitrate nitrogen concentrations above 10 mg/L (CDC, 1998). This compares to 13.4 percent of 5,520 wells surveyed throughout a nine-state region.

Huntzinger (1998) found that groundwater nitrate concentrations at different locations reflect differences in agricultural land management, and that concentrations were highest in areas of irrigated corn, permeable soils, and shallow water tables (specifically, the Platte Valley and the glaciated areas of eastern Nebraska). Nitrate levels were much lower in the nonirrigated areas of western Nebraska used predominantly as rangeland. He also found that fertilizer management plans can reduce the nitrate concentration in aquifers by amounts that vary with the stringency of the restrictions.

Other reports have also compiled information on nitrate in Nebraska's small community water supplies. One by Keefer and Lamberty (1995) describes the drinking water supplies of 521 small communities, based on information provided by HHSS and DEQ. In addition, a summary report prepared for the Public Water Supply Program (NPWSP 1997) described the state's 1,340 public water supply systems by type of system, population served, and occurrences of administrative orders.

NATURE OF THE AFFECTED COMMUNITY

Public Water Supply Systems

As of 1995, groundwater accounted for more than 81% of publicly supplied water in Nebraska and virtually all self-supplied domestic water. Moreover, of publicly supplied water drawn from surface supplies, more than 99% was used in the Omaha Metropolitan area. Therefore, groundwater is overwhelmingly the source for small community supply systems.

Nebraska has about 1,340 public water supply systems (NPWSP, 1997): 621 community systems and 719 noncommunity systems. Of those 621 community systems, 608 serve populations of fewer than 10,000 (NPWSP 1997) and thereby meet the definition of "small community systems." Most of these (451) serve incorporated villages or small cities; 23 are recognized rural water systems, and the remaining 134 are miscellaneous systems that don't fit either of these categories. The number of users served by all small community systems combined equals about 19% of Nebraska's population. The noncommunity systems are subdivided into the categories of transient (534 in Nebraska) and nontransient (185 in Nebraska), depending on how many regular, repeat users they serve.

Self-Supplied Domestic Water Use

Self-supplied domestic water served about 346,400 Nebraskans in 1995—about 21% of the state's population (NNRC, 1998). Not all of these users lived in remote, isolated homesteads. As of 1995, there were 59 Nebraska towns that had no public water systems. In addition, many unincorporated developments lack public water supplies.

Impact of Nitrate on Small Public Water Systems

Available records show that, for a period of record beginning in the 1960s and extending through 1998, 168 (37%) of Nebraska's 451 small city and village water systems have produced one or more water samples that exceeded the MCL for nitrate nitrogen (10 mg/L). Also, another 128 (28%) of these systems have had a reading between 5 and 10 mg/L. A survey compiled for this study indicates that, since 1981, the operators of small city, village, and rural systems have built or are building at least 59 water system infrastructure projects that are at least partially related to nitrate contamination. The total estimated cost of these projects is more than $24 million. The water systems that have undertaken these projects serve a combined population of about 60,000 people, so the per capita cost has averaged more than $400 per person. The most common major infrastructure improvement used by small communities to remediate a nitrate problem has been to drill a new well and construct transmission lines for it. A few communities have gone to the large expense of building a treatment plant.

Public and Private Domestic Water System Well Siting and Construction

In many cases, construction, hydrologic, and site factors contribute to nitrate problems in older wells. A well that is poorly sited, poorly constructed, or too shallow may be susceptible to small point sources of contamination that don't affect a large area. Old private domestic wells are most likely to be affected by construction and siting problems.

Determining the role of well siting in cases of nitrate contamination can be difficult. Theoretically, a poorly sited well might be drawing from the only contaminated level of the only contaminated part of the aquifer. On the other hand, some areas simply may not have any uncontaminated groundwater. Between those two extremes is a large array of potential relations between well-site characteristics and the prevalence of nitrate sources. In places where nitrate sources have increased, old, poorly sited wells might be affected earliest and most seriously.

Gosselin et al. (1996, 1997) identified several factors that could influence the occurrence of contaminants in domestic wells, and which are also applicable to public wells: "(1) well construction factors, which include casing type, installation date (age), diameter, well completed in or out of pit (i.e., top of well above the ground or in an excavated pit below the land surface), sanitary seal, and well type; (2) distance factors, which include distance to cesspool, septic systems, waste lagoons, barnyards, pasture, and cropland; and (3) hydrogeologic and site factors, which include well depth, depth to water, landscape and soil characteristics, and agricultural chemical use on premises."

Economic Costs of Addressing Nitrate Problems in Public Water Supplies

As stated above, from January 1981 through February 1998, Nebraska small cities and villages have undertaken more than $24 million worth of nitrate-related projects, which equates to more than $400 per capita. In comparison to overall water system expenditures, this number is small. In 1996 and 1997 combined, nitrate-related water system projects accounted for less than 10% of the estimated costs for all small community water project construction approved by HHSS. The need to address nitrate contamination was a major factor in 16 of the 55 wells approved for construction. The EPA (1997) has estimated Nebraska's current needs for infrastructure related specifically to meeting the nitrate standard at $8.4 million, but this compares to an overall need of almost $953 million for infrastructure improvement over 20 years. Small systems (serving fewer than 3,300 in the EPA study) accounted for nearly half ($472 million) of this need.

The greatest nitrate-related costs are incurred by communities that need to treat their water. Keefer and Lamberty (1995) surveyed 425 towns with wells and found that only 44 of them did any sort of water treatment. Most of those towns had multiple wells but no common distribution system and therefore found the cost of water treatment to be much higher than the cost of drilling a new well. Communities that build water treatment systems in response to nitrate problems also face significant costs for maintenance and for monitoring. (Any community that exceeds 5 mg/L at its point of entry must continue to sample quarterly until readings have been under 8 mg/L for four consecutive quarters.)

Although infrastructure costs for nitrate remediation may be high, they are not all paid by the water systems or consumers. Community development block grants and grants and loans from the U.S. Department of Agriculture have paid much of the cost.

Nitrates are likely to continue to be a significant issue to communities. Out of 83 communities that sought technical assistance through DEQ's Nebraska Mandates Management Initiative between May 1995 and January 1998, 42 identified nitrate concerns as a significant issue. Sixteen of these communities had received an Administrative Order (AO) to take action on a nitrate problem at some point between January 1981 and February 1998 (DEQ 1998). Nitrate problems accounted for nearly half (34 of 69) of the water quality violation administrative orders issued by HHSS from 1991 through 1997. However, recent changes in EPA standards may lead to an increase in AOs based on other drinking water properties and, hence, nitrate may account for a smaller proportion of these, even if the frequency of nitrate-related AOs remains the same.

More details about nitrate-related projects undertaken by small community water systems, and the costs incurred, are given in tables 2–4 and in figures 8 and 9 in the main text.

Economic and Social Costs to Self-Supplied Domestic Users

Customers of public water systems are not the only people affected by nitrate-related contamination. Owners of domestic wells may also face some nitrate-related expense. Increased well depth and grouting could solve many domestic well problems, but the cost of deepening a single well probably averages in the range of $1,200 to $1,500. The cost of a new well, including pump and piping, probably averages around $3,000 to $4,000. Costs can vary depending on depth of well, whether only deepening is involved, and other factors. Many private owners would probably seek to avoid such an expense. Inasmuch as the nitrate MCL is set at a level believed to protect the health of pregnant women and infants, some families that do not include such high-risk individuals might believe they can afford to exceed the MCL. Some may also find other options, such as point-of-use treatment, more affordable.

Even identifying which private wells need treatment poses a problem. In a nine-state survey (including Nebraska) by the Centers for Disease Control (GAO, 1997, p. 20), 44% of private well owners responding said their wells had never been tested for contamination, 44% said theirs had been, and 11% did not know.

Other Socioeconomic Factors

A community's population, its economic well-being, and its capacity to pay greatly influence water infrastructure decisions. Supalla and Ahmad (1997) estimated the financial capacity of 440 small Nebraska communities to pay for water and sewer improvements. They found great variations in community capacity—from 9 to 110 dollars per household per month. Yet infrastructure construction decisions also depend on other factors, such as financial obligations, expected population changes, income source types (fixed or variable), and other public works problems.

Social factors that must be taken into account in dealing with elevated levels of nitrate in drinking water include fear, inconvenience, and health risks.

Current and Future Small Community and Rural Domestic Water Demand

Future water demand will depend upon population change, water rates, climatic conditions, and conservation practices. U.S. Census Bureau figures indicate that 313 (59%) of Nebraska's 535 communities declined in population between 1970 and 1990. The University of Nebraska's Bureau of Business Research projects that the state's population as a whole will increase 13.6% between 1990 and 2010, but that increase will not be evenly distributed. The metropolitan counties (those having the largest base population) are expected to have the fastest growth. The increases will be less for large trade-center counties and even slower for counties considered small trade counties. Rural counties' populations are expected to decrease by 6.7 percent.

While population is the most important factor driving water demand, other factors also affect per capita demand. These include:

Household size.—Currently declining. Between 1980 and 1990, while Nebraska population grew 5%, the number of households grew about 10%. Small households tend to use more water per capita than larger households.

Conservation measures.—Increased awareness and adoption of such measures may lessen water demand and could provide significant savings to commercial enterprises.

Industrial and commercial use.—In an individual small community, the opening or closing of an industrial water user can significantly alter the per capita use figures, and so can the institution of conservation measures by the industrial user.

System efficiency.—Some aging systems have significant leakage, which may be controlled when new mains are installed.

Cost to the consumer.—Many of Nebraska's small communities do not meter individual water use. Metering would probably lead to some decrease in demand.

Factors That May Affect Supply

Among the environmental setting factors most relevant to rural/small community water supplies are occurrence of groundwater, depth to the water table, topography, climate, soil characteristics, vulnerability to contamination, and natural vegetation. Vulnerability to contamination is estimated based on a combination of factors: depth to the water table, time required for water to percolate down into the water table, amount of recharge, slope of the land, and the type of material making up the aquifer and the overlying soil. Figure 14 is a generalized map of groundwater vulnerability to contamination.

Legal/Institutional Factors

The array of legal and institutional factors affecting small community water supplies is so large that even providing a list of relevant laws and regulations can be confusing to the casual reader. The main text of this report examines these factors in several categories: (1) the regulatory framework (including regulations pertaining to wells, water systems, and source-water protection), (2) technical assistance programs and education, and (3) funding sources. Those categories include state, local, and Federal government responsibilities. Private assistance is also possible in categories 2 and 3. In most instances, Federal laws and regulations are in practice implemented through parallel state regulations.

Private domestic wells are not regulated under the Federal Safe Drinking Water Act, nor are they subject to state or Federal water quality testing requirements. They must, however, meet state well-construction standards.

NITRATE DATA ANALYSIS

Background

Historical community water system nitrate data is maintained by HHSS in a number of forms: (1) water quality data collections printed by the Nebraska Department of Health in 1967, 1969, 1971, 1973, 1975, 1982, and 1984; (2) hard-copy tabulations of sampling data in separate files for each community water system; (3) some unpublished historical water quality data from 1952–53 and 1947–48 in HHSS files; and (4) a computerized electronic file containing more than 14,000 sampling records from small systems, collected between 1970 and 1999.

Through time, Nebraska communities have completed required sampling, and HHSS has maintained records of samples. However, those records can be in one or more of the above forms. HHSS has copied many of its records to electronic format, but for a number of past years, these electronic files are incomplete.

The analysis of historical community water system nitrate data is further complicated by the fact that sampling requirements have changed through time. Prior to 1993, samples were required from the distribution system. Since 1993, operators of community and nontransient systems have been required to monitor all groundwater entry points at least annually. However, if a sample shows a nitrate concentration of 5 mg/L or higher, then samples must be taken quarterly until samples for four consecutive quarters are shown to be below 8 mg/L. Quarterly monitoring is also required for water that is above the MCL at the entry point but is treated to meet standards. Changes in sampling requirements through time can be traced partially to Safe Drinking Water Act amendments. A final complication is that communities change their water systems through time, in some cases taking older, poorer wells out of production and bringing new wells on line.

The available sample record is generally much smaller prior to about 1984. Much of the information provided in this report is for the 451 small city and village water systems, rather than for all 608 of the community water systems.

Methodology

All available HHSS files, including the paper-copy files, reports, and electronic files, were used in compiling almost all the aggregate nitrate sampling data used in this report. However, the paper file was checked only for systems that had nitrate readings of 5 mg/L or higher. Data were collected separately for the 1961–80 and 1981–98 periods.

Several cautions should be considered when evaluating the nitrate-sampling data presented here:

1. Far more sample records are available for the period from 1984 through 1998 than for the period prior to 1984.

2. The analyses were compiled as one indicator of whether nitrate had *ever* been a significant concern to many small community water systems, not as an indicator of major ongoing problems.

3. The database includes both point-of-entry and distribution-system data.

4. These listings do not distinguish between systems that had only one high reading and those that had more than one.

5. A single nitrate sample in excess of 10 mg/L does not indicate that a community is out of compliance with state regulations. When a single high reading is reported, a second sample is taken, and the community is considered to be in compliance if the average of the two samples is below the MCL.

6. Some of the readings represented here came from backup or emergency wells.

7. This listing indicates only a past high reading or readings and does *not* imply ongoing nitrate problems. Only a very few systems are currently under administrative orders to address nitrate problems.

8. The earliest data used are from a January 1967 Department of Health report, which did not record the year samples were taken, though a handwritten annotation suggests some were taken as early as 1961. Sample collection dates prior to 1970 are generally uncertain.

Findings

According to the data analyzed, 34% of small city and village water systems statewide had no occurrences of nitrate above 5 mg/L throughout the period from 1981 through 1998, thus indicating no apparent nitrate problems. Thirty-seven percent of small city and village systems have exceeded the MCL at least once, indicating that at one point in time they experienced a nitrate problem. The remaining systems (28%) have not exceeded the MCL but have experienced nitrate levels above 5 mg/L, indicating a need for caution.

However, this analysis demonstrates and reinforces the importance of looking at the nitrate problem in the context of particular groundwater regions rather than statewide. For instance, although the statewide figures showed 37 percent of the systems analyzed had exceeded the MCL, the corresponding percentage ranged from 0 to 56 percent within individual groundwater regions. Similar wide variations among the regions were found in the 5–10 and <5 mg/L categories. Part of the reason for the variation appears to be sample size, but there also appear to be some significant regional differences. (See figure 19.)

Small community water supply systems by system type and maximum nitrate reading, through 1998[1]

Maximum nitrate reading	ALL small community water systems (608 systems)		Small city and village water systems ONLY (451 systems)	
>10 mg/L	188	(31.1%)	168	(37.2%)
5–10 mg/L	160	(26.4%)	128	(28.4%)
<5 mg/L	257	(42.5%)	155	(34.4%)
Total	605		451	

[1] Earliest records used are from a January 1967 report that did not record the year of sample collection, but some samples may date to as early as 1961.

ALTERNATIVES FOR PUBLIC WATER SUPPLY SYSTEMS

In most instances, the least expensive option for addressing potential groundwater contamination is to prevent contamination from occurring in the first place. However, the effectiveness of actions designed to prevent or limit contamination is not always well established and can be difficult to gauge for a specific situation. Such measures also tend to be long-term solutions, and a community may not have time to wait. Some options, such as land purchase, can be quite expensive. Others may involve regulation of a range of activities.

Various treatment methods have proven to be effective for remediating nitrate contamination, but these may be too costly for some small communities. Finding a substitute water supply (most notably, by drilling a new well) is the approach most commonly taken but may provide only temporary relief from nitrate problems. Connecting to an outside distribution system can work well but is not feasible for many communities, especially in remote areas. The alternatives presented below are in addition to the option of continuing current operations and taking no new action. The viability and legality of that option vary with the circumstances of the individual systems.

All of the following specific alternatives are discussed in detail in the main text:

Preventative Methods:

1. Wellhead Protection Programs
2. Groundwater Management Areas for Water Quality
3. Land Based Zoning/Easements/Purchase
4. Voluntary Landowner Action Through Education Programs
5. Voluntary Landowner Action Through Incentive Programs

Treatment Methods:

6. Reverse Osmosis

7. Nanofiltration
8. Ion Exchange
9. Electrodialysis
10. Denitrification Process/Reduction (Ex Situ)
11. Denitrification Process (In Situ)
12. Community Maintenance of Point-of-Use Water Treatment Systems

Substitute Water Supply:

13. New Well and Well Location
14. Same Well Location, Different Aquifer Layer
15. Blending Water from Multiple Wells
16. Storage and Blending
17. Substituting Surface Water for Groundwater
18. Conservation of Existing Supply

Other Distribution Systems:

19. Connecting to or Expanding Existing Rural Water Systems or Other Systems
20. New Rural or "Regional" Systems

ALTERNATIVES FOR SELF-SUPPLIED RURAL DOMESTIC WATER USERS

Generally, because of cost constraints, private well owners have fewer alternatives for addressing water quality problems than are available to public systems. Ten alternatives for self-supplied domestic water users are described briefly in the main text:

1. Preventative Methods
2. Point-of-Use Treatment
3. Deepening Well/Well Repair
4. New Well
5. Connection to an Existing Public Water System
6. Bottled Water
7. Well Operation/Conservation/Storage/Blending
8. Well Testing
9. Ceasing Use of Well
10. Continued Use of Well Despite High Nitrate Levels

CONCLUSIONS

Nitrate Conditions

More than one-third of Nebraska's small city and village community water systems have had no nitrate reading higher than 5 mg/L during the period of record and, therefore, have experienced no apparent drinking water problem due to nitrates. Roughly 28% of the community systems have had at least one reading in the range of 5–10 mg/L, and 37% have had a reading above the MCL of 10 mg/L. Many small cities and villages have experienced elevated nitrate levels at some time. However, at any one time, all but a very few systems are generally in compliance with required standards, as systems that have had a violation take steps to come back into compliance.

This investigation has shown that many factors affect the potential for nitrate contamination to groundwater supplies for Nebraska's small communities. Compared to most states, Nebraska has large areas of permeable soils, croplands, irrigation, and fairly shallow water tables. Wherever two or more of these conditions overlap, there are likely to be continuing challenges in limiting nitrate levels in groundwater.

Community Response to Nitrate Contamination

Since 1981, Nebraska small cities, villages and rural water systems have built or are in the process of building 59 nitrate-related projects with a total estimated final construction cost of more than $24 million. Drilling a new well appears to have been the single most common response. The study team reviewed a list of communities that have undertaken such projects and evaluated the effectiveness of these changes by reviewing plotted nitrate data from the HHSS electronic database. This evaluation identified six communities that successfully eliminated nitrate problems simply by adding new wells, but it found eight others that tried the same approach, only to see nitrate levels rebound within a few years. Communities that added treatment capability have maintained acceptably low nitrate concentrations ever since. A small community considering changing its water supply should study the experiences of these other communities before deciding on a course of action.

Alternatives for Small Communities

Nebraska has a myriad of geologic and water quality conditions and many different types of water system infrastructure. Hence, no single solution to nitrate contamination can be expected to fit all communities. Prevention has major cost and environmental advantages but is slow or ineffective for addressing problems that have already reached a critical stage. Drilling a new well is the most common approach used by communities. However, if the geologic conditions are not right or if the remaining wells in a system continue to worsen, the problem can return. Treatment systems can solve the problem but are often very expensive for small communities, have high maintenance costs, and can require a high level of skills for their upkeep. Only a few of Nebraska's small communities have installed treatment systems for the primary purpose of addressing nitrate problems. Water system operators facing such problems should consider, in turn, each of the 20 methods described in the section "Alternatives for Public Water Supply Systems."

POTENTIAL COURSES OF ACTION — GENERAL

1. Keep plots or graphs of nitrate concentration over time for each point of entry into each water system. This may assist the community in detecting long-term trends and instituting preventative programs. Both the individual communities and HHSS Department of Regulation and Licensure could keep the plots.

2. Implement wellhead protection. Communities that have nitrate concentrations above 5 mg/L would make full use of the DEQ's Source Water Assessment Program Information by (1) setting up wellhead protection areas, (2) implementing best management practices, and (3) making full use of NDEQ's source-water assessment program.

3. Provide incentives for adoption of groundwater quality oriented best management practices (BMPs) in wellhead protection areas. This could be done through a state-level program that would provide incentive funds and administrative assistance for wellhead protection area BMPs when a community requests assistance.

4. Create additional "circuit-rider" programs for providing assistance to communities. Such personnel could, for instance, assist in setting up wellhead protection programs. Circuit riders to assist with monitoring and with water system operation and maintenance should also be considered. NDEQ, NRDs, NRWA, and HHSS could cooperate on this effort.

5. Fund an incentive program to install monitoring wells upgradient of the source wells for community water supplies, at or beyond the 20-year time-of-travel limit. Such a program could be administered by HHSS and funded through the Environmental Trust or other sources.

6. Enhance programs to inform rural well owners of testing needs and potential risks. This effort could build on existing programs of the Cooperative Extension Service and the Natural Resources Districts.

7. Consider incentives for upgrading or replacing dug wells and possibly other domestic wells that fail to meet an identified standard. Also, make sure that programs are adequately funded to address the resulting closing and capping of those wells.

8. Inform local health care providers of community nitrate levels in those communities that have experienced readings above 8 mg/L.

INTRODUCTION

THE PROBLEM

Nitrate nitrogen in groundwater is a problem in many parts of the United States, especially where groundwater is used for domestic water supplies. Studies by the U.S. Geological Survey (Mueller et al., 1995) show increasing concentrations of nitrogen in many groundwater-based domestic supplies nationwide. In Nebraska, groundwater accounts for more than 80% of public water supply withdrawals and virtually all private rural domestic water supply.

Nitrate nitrogen is known to cause a disease called methemoglobinemia, also known as "blue baby syndrome." This condition occurs when bacteria in the stomach convert nitrate to nitrite. The nitrite then passes into the bloodstream, where it oxidizes iron in the hemoglobin, thereby inhibiting the blood's ability to carry oxygen. Humans older than six months usually develop stomach acids that prevent the nitrate breakdown, but the disease can be fatal to young infants and to adults who lack certain enzymes. Methemoglobinemia gives a characteristic blue cast to its victims' lips and fingernails (EPA, 1996). Waterborne nitrates may also be converted to carcinogenic nitrosamines when consumed (Gosselin et al., 1996). Hartman (1983) found a correlation between nitrate intake and gastric cancer.

Concerns over potential future groundwater quality and the high proportion of Nebraska's domestic water supply obtained from groundwater helped generate initial interest in this study. Previous studies had shown high levels of nitrate nitrogen in groundwater in some parts of Nebraska (Exner and Spalding, 1990). Previous examination of rural domestic wells had indicated a problem with nitrate levels in some of those wells (Spalding, 1991). These studies contributed to a growing concern that some sources of nitrogen, such as agricultural fertilizers, livestock operations or septic tanks, might pose increasing risks. In addition, data collected by the Nebraska Health and Human Services System (HHSS) show that 168 small city and village water systems have exceeded the Federal maximum contaminant level (MCL) for nitrate nitrogen at least once during a period of record that extends back into the 1960s. These systems are listed in table 1 and their locations are shown on figure 1. How small community water supplies were being affected by nitrate, the cost of nitrate to those communities and what their options might be were other concerns raised.

Well placement, well construction, and hydrogeologic characteristics all play major roles in determining whether a well becomes contaminated. Thus, in many cases, nitrate problems in drinking water can be resolved (at least temporarily) simply by constructing a new well, and that is the method most commonly used by small Nebraska communities. Nevertheless, the role of human activity in introducing nitrate into the environment is very significant. Fertilizers, animal waste, waste lagoon sludge, septic systems, and nitrogen-bearing minerals in the soil have been cited as possible sources of contamination in past studies. Tonnages of fertilizer consumed in Nebraska more than quadrupled between the early 1960's and the late 1970's. However, since that time, the tonnages consumed have not increased greatly. Similarly, cattle numbers increased significantly (about 65%) between 1950 and 1970 but were still near 1970 levels in 1996. Hog and pig numbers increased 64% from 1950 to 1980, but were still near the 1980 levels in 1996 (although they have dropped significantly since then). However, permit applications for livestock waste facilities have been at high levels since 1996. U.S. Census of Housing figures indicated that 117,460 housing units in the state were served by septic tanks or cesspools in 1990. Unpublished working estimates from the Nebraska Department of Environmental Quality (DEQ) indicate Nebraska may have as many as 200,000 to 250,000 septic tanks, with 8,000 to 10,000 more being added each year.

The increases in fertilizer use, livestock populations, and numbers of septic tanks do not necessarily indicate a growing nitrate problem. Improvements in fertilizer management, animal waste management, and septic tank design and construction can decrease the potential for contamination. However, there is cause for concern that human activities may contribute to increased levels of nitrate nitrogen both in groundwater and in the vadose zone above the water table.

The U.S. Environmental Protection Agency has set a maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) for nitrate nitrogen in drinking water (EPA 1995). A recent statewide assessment (Gosselin et al., 1997) sampled 1,808 individual domestic wells and found that 19% of them exceeded the MCL for nitrate, although percentages varied widely by region (3% to 39%). Depending upon the groundwater region, the degree of nitrate contamination in rural domestic drinking water wells had remained generally unchanged or had only slightly increased since the previous statewide assessment conducted from 1985 to 1989. That study did indicate that domestic rural water quality varies substantially from one groundwater region to another and is affected by well characteristics, distance to potential contamination sources, and hydrogeological and site characteristics. One of the intents of this Bureau of Reclamation study is to analyze existing data from small community water supply systems and characterize how nitrate contamination has affected those systems.

PURPOSE OF THIS STUDY

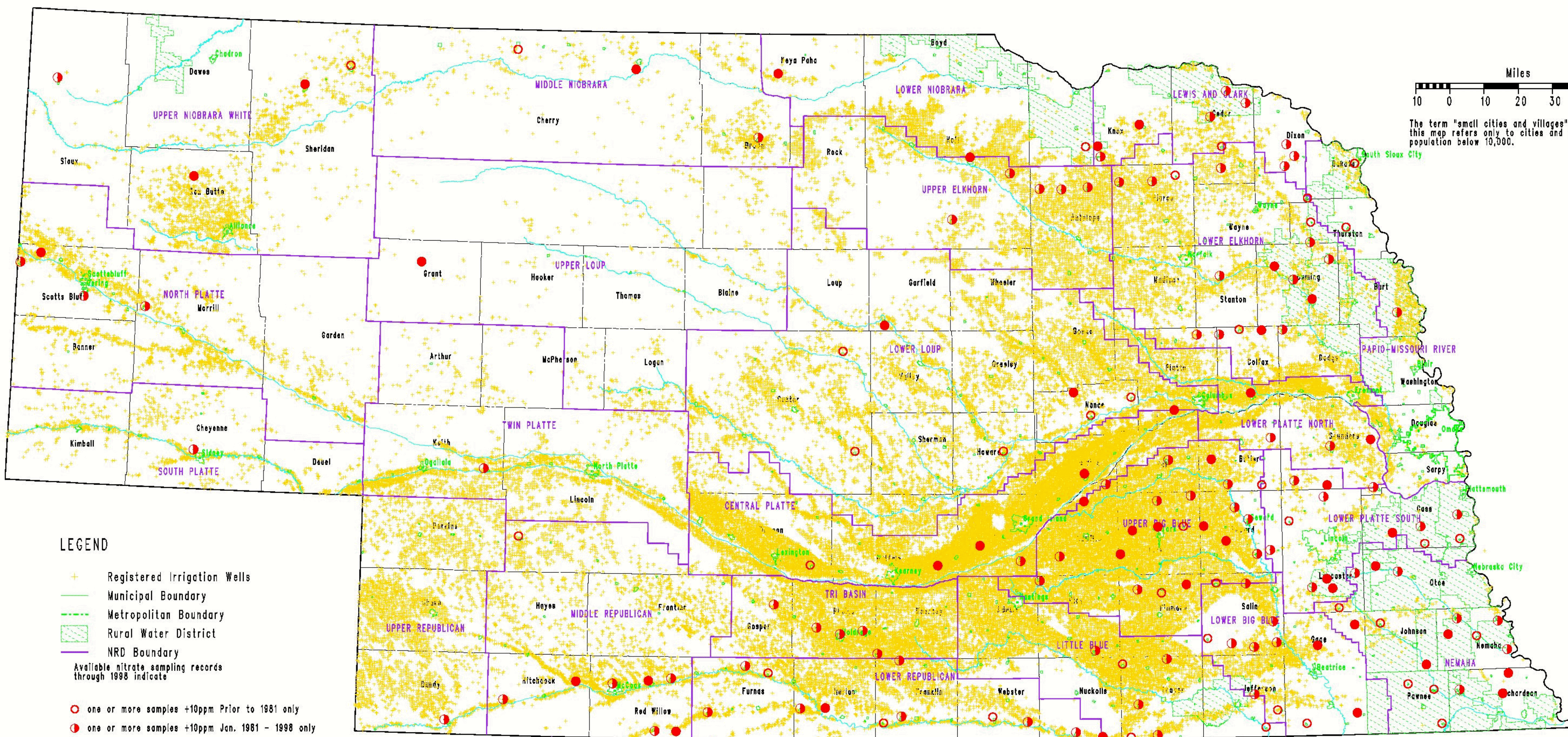
Nebraska’s large irrigated acreage, its agriculturally based economy, and the widespread use of groundwater for domestic and municipal supplies all help stimulate regional interest in groundwater quality. The purpose of this study was to investigate how nitrate contamination problems affect the state’s small community and rural domestic water supplies, analyze trends, and identify possible alternatives for meeting future needs. The study had four principal objectives:

1. Evaluate nitrate contamination conditions and trends in Nebraska, including available small community water supply nitrate testing records,
2. Examine nitrate-related infrastructure problems and needs of small community water systems,
3. Explore alternatives for addressing community water supply problems related to nitrate, and
4. Indicate potential courses of action.

SMALL CITY AND VILLAGE WATER SYSTEMS THAT HAVE HAD HIGH NITRATE OCCURRENCES

Figure 1

Nebraska Natural Resources Commission



LEGEND

- Registered Irrigation Wells
- Municipal Boundary
- Metropolitan Boundary
- Rural Water District
- NRD Boundary

Available nitrate sampling records through 1998 indicate

- one or more samples +10ppm Prior to 1981 only
- one or more samples +10ppm Jan. 1981 - 1998 only
- one or more samples +10ppm Both prior to 1981 and 1981 - 1998

Of approximately 451 small city and village systems there is a record of 168 or about 37% having one or more occurrences of +10ppm on a well or system point of entry: 84 After 1980 only, 39 Before 1981 only, and 45 Both before January 1981 and after.

NOTES:
Does not include community water systems other than small city and village systems.
-Earliest available records in Nebraska Dept. of Health reports date to a Jan. 1967 report which included data from 1961-1967. Completeness of record is uncertain.

NOTES:
For more sample records for nitrate are available for the period 1984 to date. The draft of this map maybe missing a very few systems with 1998 samples above 10ppm. Final checks of those systems were still being made at the time this was printed.

SOURCES:
Nebraska Health and Human Services System paper and electronic files
Nebraska Department of Health-Reports on: Chemical Analyses/ Public Drinking Water Supply/ or Drinking Water Quality
1967 1969 1973 1975 and 1984
Map drafted by Nebraska Natural Resources Commission

Table 1. Nebraska small-city and village water systems reported to have had high nitrate occurrences (through 1998)

The following listing includes only systems for cities and villages with populations less than 10,000, and *no other* types of community systems. See figure 1 for geographic distribution of these systems. Several cautions should be considered when evaluating the nitrate-sampling data presented here:

1. Far more sample records are available from the period from 1984 through 1998 than for the period prior to 1984.
2. The analyses were compiled as one indicator of whether nitrate had been a significant concern to many small-community water systems, not as a definitive indicator of major problems.
3. The database includes both point-of-entry and distribution-system data.
4. These listings do not distinguish between systems that had only one high reading and those that had more than one.
5. Although all systems listed here had at least one nitrate sample in excess of 10 mg/L, not all were deemed to be in violation of state regulations. When a single high reading is reported, a second sample is taken, and the community is considered to be in compliance if the average of the two samples is below the MCL.
6. Some of the readings represented here came from backup or emergency wells.
7. This listing indicates only a past high reading or readings and does *not* imply ongoing nitrate problems. Only a very few systems are currently under administrative orders to address nitrate problems.
8. The earliest data used are from a January 1967 Department of Health report, which did not record the year samples were taken, though a handwritten annotation suggests some were taken as early as 1961. Sample collection dates prior to 1970 are generally uncertain.

[Sources: Nebraska Department of Health (1967, 1969, 1973, 1975, 1984) and electronic files of the Nebraska Health and Human Services System, through February 1998]

Systems having one or more nitrate readings >10 mg/L prior to 1981 only

Auburn, City of
Avoca, Village of
Byron, Village of
Clarkson, City of
Cody, Village of
Coleridge, Village of
Dakota City, City of
Davenport, Village of
Diller, Village of
DuBois, Village of
Dwight, Village of
Edison, Village of
Emerson, Village of

Fairmont, Village of
Firth, Village of
Friend, City of
Fullerton, City of
Genoa, City of
Gordon, City of
Malcolm, Village of
Mason City, Village of
McLean, Village of
Naponee, Village of
Odell, Village of
Overton, Village of
Red Cloud, City of

Sargent, City of
St. Paul, City of
Steele City, Village of
Steinauer, Village of
Sterling, Village of
Table Rock, Village of
Thurston, Village of
Tobias, Village of
Union, Village of
Waco, Village of
Wallace, Village of
Walthill, Village of
Winnetoon, Village of

Systems having one or more nitrate readings >10 mg/L since January 1981 but no record of any such reading before 1981

Ainsworth, City of
Allen, Village of
Arapahoe, City of
Ashland, City of
Bancroft, Village of
Bartley, Village of
Bayard, City of
Beemer, Village of
Belden, Village of
Benedict, Village of
Edgar, City of
Funk, Village of
Gering, City of
Giltner, Village of
Grafton, Village of
Gresham, Village of
Guide Rock, Village of
Harrison, Village of
Hartington, City of
Hildreth, Village of
Pender, Village of
Peru, City of
Plainview, City of
Pleasant Dale, Village of
Royal, Village of
Seward, City of
Sidney, City of
Smithfield, Village of
Sprague, Village of
Stamford, Village of
Stanton, City of

Benkelman, City of
Bennet, Village of
Bloomington, Village of
Brock, Village of
Bruning, Village of
Bruno, Village of
Brunswick, City of
Chambers, Village of
Chester, Village of
Creighton, City of
Holdredge, City of
Hordville, Village of
Humboldt, City of
Jansen, Village of
Leigh, Village of
Loomis, Village of
Lyman, Village of
Martinsburg, Village of
McCook, City of
Milford, City of
Staplehurst, Village of
Stratton, Village of
Superior, City of
Swanton, Village of
Tekamah, City of
Trumbull, Village of
Ulysses, Village of
Unadilla, Village of
Valparaiso, Village of
Wahoo, City of

Creston, Village of
Danbury, Village of
Davey, Village of
Deshler, City of
DeWitt, Village of
Dodge, Village of
Doniphan, Village of
Dorchester, Village of

Murray, Village of
Nemaha, Village of
Obert, Village of
Orchard, Village of
Osceola, City of
Osmond, City of
Page, Village of
Paxton, Village of

Waterbury, Village of
Weeping Water, City of
Western, Village of
Wilber, City of
Wilcox, Village of
Wilsonville, Village of
Wynot, Village of

Systems having one or more nitrate readings >10 mg/L both before and after January 1981

Adams, Village of
Bazile Mills, Village of
Belgrade, Village of
Bloomfield, City of
Bradshaw, Village of
Burwell, City of
Hardy, Village of
Hemingford, Village of
Henderson, City of
Hickman, Village of
Howells, Village of
Hyannis, Village of
Pickrell, Village of
Rising City, Village of

Central City, City of
Ceresco, Village of
Culbertson, Village of
Duncan, Village of
Elk Creek, Village of
Indianola, City of
Johnson, Village of
Lebanon, Village of
Liberty, Village of
Marquette, Village of
Roca, Village of
Rushville, City of

Elmwood, Village of
Exeter, Village of
Gibbon, City of
Goehner, Village of
Morrill, Village of
O'Neill, City of
Orleans, Village of
Palmyra, Village of
Schuyler, City of
Shubert, Village of

Many specific questions related to these objectives were considered in the course of this study. These included, for example,

1. What do sampling records for small community supplies and from other sources show about nitrate levels and trends?
2. Are potential sources of introduced nitrogen increasing?
3. What has been the small community response to high nitrate levels and what has been the cost?
4. What are small community and rural domestic options for addressing high nitrate levels and how might policy changes assist those small communities?

The data available were insufficient to fully answer all of these questions. Trend data were especially sparse. However, this report does provide much information relevant to these points.

STUDY DEVELOPMENT

In May 1996, the Bureau of Reclamation and the Nebraska Natural Resources Commission (NNRC) signed an agreement to initiate this general investigations study. It was developed as a 50/50 cost share between the Reclamation and the NNRC. Reclamation's share of the study was financed under its program of technical assistance to states; the NNRC share was to be in the form of in-kind services. As described in the original plan of study, the projected completion date was October 1998.

Significant changes were made in study scope and methodology during the course of the study. The scope of the study was narrowed to focus more exclusively on nitrate, and the study's purpose was also modified. The original study design had envisioned selection and use of a detailed study area and extrapolation of the study area results for use on a statewide basis. (See appendix I.) However, as the study proceeded it became apparent that results from a small study area could not be used to portray statewide conditions, because of the great geological, hydrological, and environmental differences between regions. The detailed study area approach was then dropped in favor of using statewide data.

EXISTING INFORMATION ON NITRATE CONDITIONS AND TRENDS

Many reports have noted that a certain amount of nitrate occurs naturally in groundwater, even in remote, uncontaminated areas. According to Mueller and Helsel (1996), "Nitrate concentrations in samples from background sites generally were less than 2 mg/L for ground water . . . ." Earlier, Bachman (1984) had reported that "Nitrate rarely occurs naturally in ground water in concentrations greater than 3 mg/L . . . ." In this study, wells with values greater than 3 mg/L are considered to have been affected by human activity.

A number of studies have been conducted to assess existing nitrate conditions for Nebraska's groundwater. The statewide assessments by Exner and Spalding (1974, 1990) were based on thousands of measurements of pesticides and nitrates from various types of wells throughout the state. In the 1990 report, Exner and Spalding concluded that nitrate-nitrogen concentrations exceed the MCL of 10 mg/L in groundwater beneath several areas of Nebraska. Based on their studies, the most obvious areas of nitrate contamination coincide with irrigated croplands. These include, especially, the north side of the Platte Valley from Kearney to Columbus, the south side of the Platte Valley in Phelps and Kearney Counties, and an area north of the Elkhorn River in Holt County. A very large proportion of wells in these areas have elevated nitrate concentrations. The most vulnerable areas are places where irrigated crop production occurs on well-drained soils with less than 50 feet to the water table. Nearly all of these highly vulnerable areas are used for corn production with little, if any, crop rotation. Although previous studies had reported non-point-source nitrate contamination of groundwater in these areas, data compiled by Exner and Spalding (1990) indicated that the problem is dynamic and that both the magnitude and the areal extent of the contamination are increasing.

Wells sampled for the Exner and Spalding studies were classified in five categories: irrigation, public supply, domestic, stock, and monitoring. As Exner and Spalding (1990) explained, these different types of wells vary in their vulnerability to nitrate contamination. Irrigation and public supply wells are required to produce large volumes of water and therefore are typically designed to draw simultaneously from several different levels of the aquifer; the water they produce is a composite of ground water from these various depths. Domestic and stock wells generally yield much smaller volumes and therefore will commonly draw from only a single interval (usually a shallow interval, which is more subject to contamination than the deeper levels). Monitoring wells generally are installed only where water quality problems are already known or suspected; therefore, they are expected to have higher average nitrate levels than any of the other well types.

For the assessment by Hammer (1980), the Nebraska Department of Health tested 451 community water systems for inorganic chemicals and found that 18 of them exceeded the MCL for nitrate. Hammer concluded that the best option at that time was to protect and prevent contamination of the aquifer used as a source of drinking water and to discontinue all other uses. A second option was to reserve a deeper, semiconfined aquifer for municipal use by excluding penetration of irrigation wells. If neither of these options were feasible, Hammer (1980) offered only one other method of preventing nitrate contamination of the groundwater supply: that is to restrict fertilization and irrigation in the recharge zone surrounding community wells.

Probably the best assessment of existing domestic rural water quality and the best attempt to determine groundwater quality trends were presented in the recent report by Gosselin et al. (1996; summarized in Gosselin et al., 1997). These authors compiled and analyzed (1) water quality data from individual domestic wells and (2) well-construction data collected as part of two statewide assessments—from 1985 to 1989 and from 1994 to 1995. Then they separated these data into those representing 13 groundwater regions (GWRs) and evaluated them region by region. (See figure 2 for the distribution of GWRs.) Their findings are summarized as follows, in the abstract from Gosselin et al. (1997):

> For this statewide assessment, 1,808 wells were sampled and a data base compiled that included water-quality data (NO_3-N, pesticides, coliform bacteria) and site-specific data collected at each location. Domestic, rural water quality in Nebraska varies substantially from one ground water region to another and is a function of well characteristics, distances to potential contamination sources, and hydrogeologic and site characteristics. The percentage of wells with nitrate concentrations exceeding the 10 ppm MCL for NO_3-N ranged from 3% to 39%, depending on the ground water region. This large range of values indicates the inadequacy of stating that an average of 19% of domestic wells in Nebraska are contaminated by nitrates. This statistic does not describe the nature, extent, and variability of the contamination problem. Depending on the ground water region, the degree of nitrate contamination in rural domestic drinking water wells has remained generally unchanged or has only slightly increased since the last statewide assessment from 1985 to 1989. To improve the quality of domestic drinking water will require a combination of activities, including the application of best management practices specific to a ground water region and individual action at rural households, such as conducting sanitary surveys of existing wells before installing new wells.

The full report (Gosselin et al. 1996) gave more details on the change in nitrate levels between the two statewide assessments:

> Fifty percent of the 1,805 domestic wells analyzed for nitrate-nitrogen have concentrations less than 2.7 ppm. This differs only slightly from the median value of 2.5 ppm for these same wells from the 1985–1989 study. The minor shift in the median values is reflected in an increase in the number of wells having nitrate-nitrogen concentrations greater than 7.5 ppm . . . . Between the sampling periods, the number of wells with nitrate-nitrogen greater than the 10 ppm MCL increased by about 2 percent. Although slight increases are suggested statewide, wells in groundwater regions 2, 6, 7, 10, 11, and 12 showed no statistically significant change. Wells in the other six regions (1, 4, 5, 8, 9, and 13) had statistically significant increases in their concentrations. Region 3 had insufficient data for analysis.

The Gosselin et al. study points out the difficulty in using water quality data from different types of wells and from various locations throughout the state of Nebraska when trying to assess statewide trends for nitrate in groundwater. The authors of that study emphasized that they assessed only the quality of individual rural domestic water supply systems, not groundwater quality per se. Because of the many complex interrelationships that affect groundwater quality, they cannot readily isolate the effects of individual factors.

In many places, communities and NRDs have implemented “best management practices” (BMPs) to attempt to protect the water quality of community wells. An attempt was made to evaluate nitrate data received from NRDs, but the data were found to be too variable to reveal any clear trends.

A recent U.S. Geological Survey report (Huntzinger, 1998) describes how nitrate content in water is related to agricultural land management in central Nebraska. The report indicates that nitrate concentrations in water at different locations reflect the differences in agricultural land management within the area. The following excerpt summarizes some of Huntzinger's (1998) most important findings. The "subunits" discussed here generally correspond to GWRs shown in figure 2, as explained in the bracketed annotations.

> The Platte Valley subunit includes extensive areas of irrigated corn, permeable soils, and shallow ground water—all characteristics that increase the vulnerability of ground water to agricultural contaminants. The Glaciated Area subunit [largely the same as GWRs 10 and 11] also has extensive areas of corn and other row crops. Consequently, concentrations of nitrate in shallow ground water are substantially larger in the Platte Valley and the Glaciated Area than in the Sandhills subunit [≈GWR 1], which is mostly rangeland, and the Loess Hills area [≈GWR 8], which is predominantly rangeland mixed with cropland. Approximately 45 percent of the shallow wells sampled in the Platte Valley and more than 25 percent of the shallow wells in the Glaciated Area exceeded the MCL of 10 mg/L for nitrate in drinking water. In contrast, 75 percent of the shallow wells in the Loess Hills contained less than 5 mg/L. Nitrate concentrations in the deeper wells in the Platte Valley and the Glaciated Area were significantly smaller than in the shallow wells.

Huntzinger (1998) also shows that fertilizer management plans can reduce the nitrate concentration in aquifers by amounts that vary with the stringency of the restrictions. The report documents the large reductions in nitrate concentrations achieved when the Central Platte Natural Resources District (CPNRD) implemented stringent BMPs:

> Their Study Unit team analyzed CPNRD data collected from 1974 through 1994 from selected irrigation and domestic wells. Median nitrate concentrations, in areas that were assigned the most stringent guidelines, increased from about 8 mg/L in 1974 to about 18 mg/L in 1986. After implementation of the fertilizer-management strategy, the median nitrate concentrations in domestic wells decreased from 18 mg/L in 1986 to less than 2 mg/L in 1994.
>
> However, despite the most stringent guidelines, nitrate concentrations in nearly 25 percent of the wells in the area continued to exceed 20 mg/L in 1994. Therefore, it is possible that some areas where the most stringent guidelines apply have not been as responsive to the management strategy as others. Nitrate concentration for different years, under moderate guidelines, did not differ significantly. Median nitrate concentrations in water samples from the domestic wells in the minimal management areas showed little change.

An additional source of information is "A Survey of the Quality of Water Drawn from Domestic Wells in Nine Midwestern States" (CDC, 1998). The nitrate-related results from this study are mapped in figure 3. The survey included 598 domestic wells in Nebraska, and 14.7% of these had nitrate levels above the 10 mg/L MCL—the fourth highest percentage among the nine states.

Two other reports were reviewed. One was a report by Keefer and Lamberty (1995), which describes the drinking water supplies of 521 communities that have a population of less than 10,000, based on information provided by HHSS and DEQ. The water sources, existing

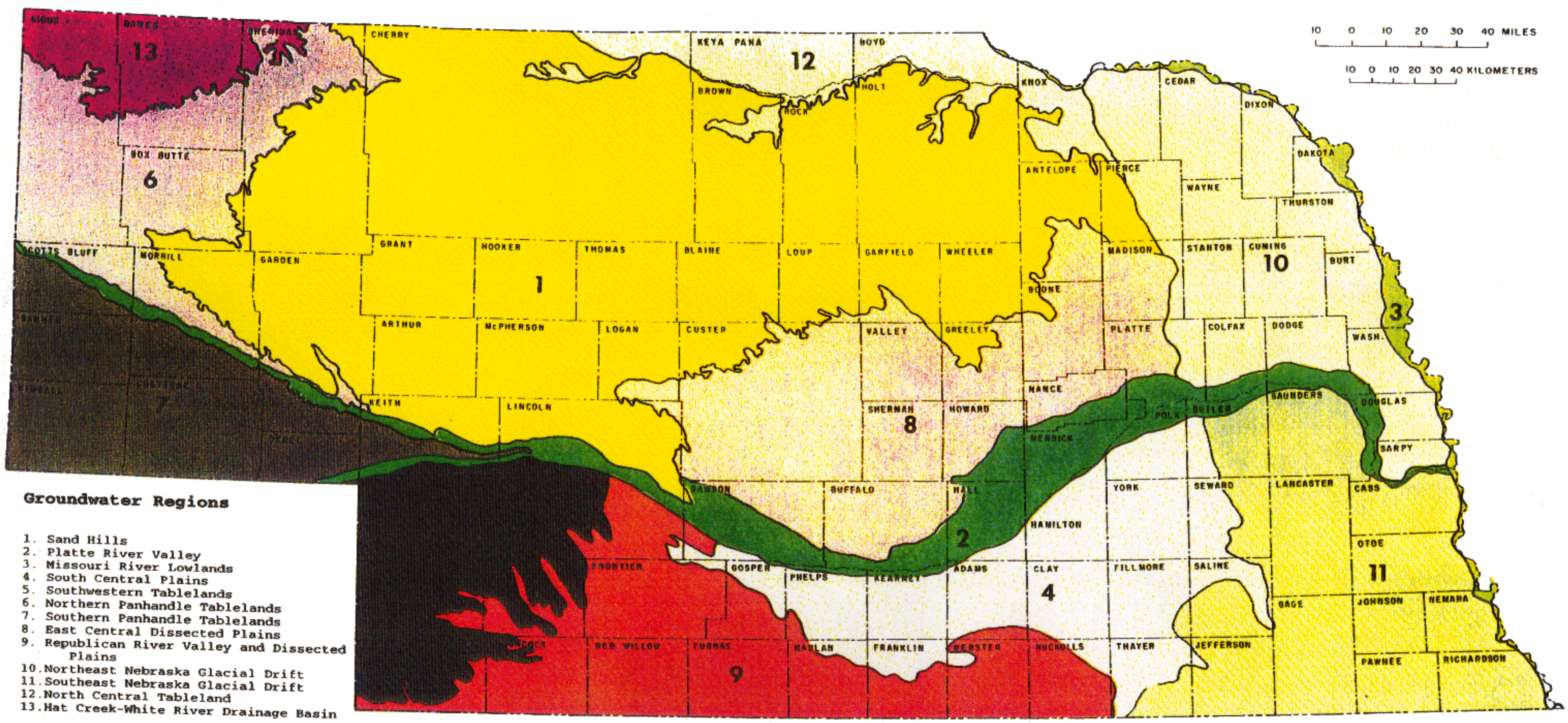


Figure 2 — Groundwater Regions in Nebraska

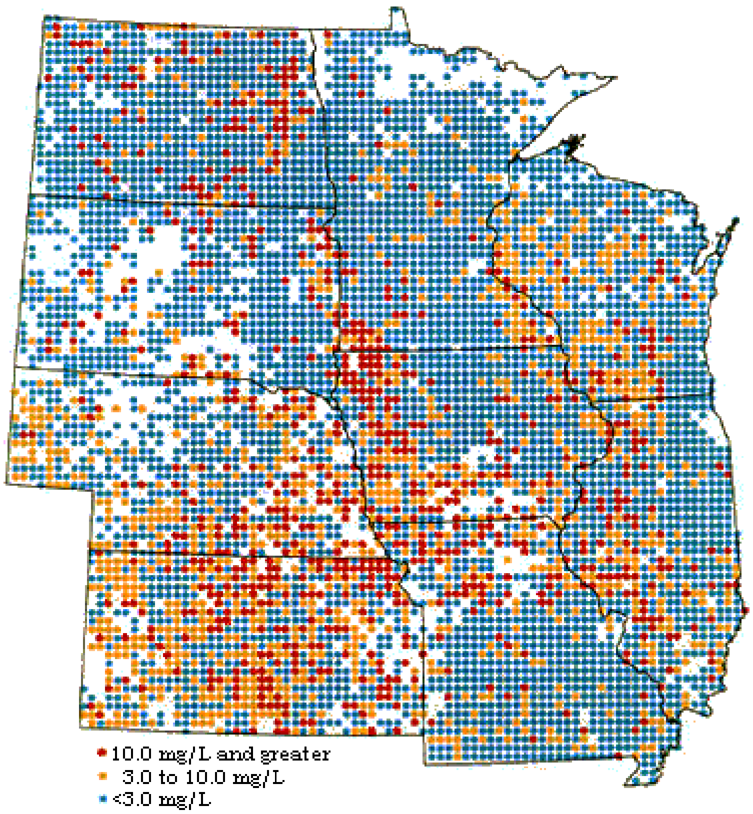


Figure 3.

Nitrate levels in water samples collected in 1994 from domestic wells in nine Midwestern states. (Source: CDC, 1998.)

distribution system, and population served were categorized for each community water supply system. Information on these water supply systems is contained in the computer file "DRINKWAT," which describes the number of wells in each drinking water facility and notes whether the system is a combination or single-well system. In addition, the 1996 amendments to the Federal Safe Drinking Water Act require each state to write an annual summary report for the Public Water Supply Program. The 1997 summary report (NPWSP 1997) described the state's 1,340 public water supply systems by type of system, population served, and occurrences of administrative orders.

NATURE OF THE AFFECTED COMMUNITY

PUBLIC WATER SUPPLY SYSTEMS

As of 1995, about 79% of Nebraska's domestic water was provided by public water supply systems, with the remainder being self-supplied (figure 4) (NNRC, 1998). Domestic water use accounted for about 69% of total water use by public water systems. The remaining 31% was used for industrial, commercial, thermoelectric, or other uses, or was lost in transmission (NNRC, 1998). Groundwater accounted for more than 81% of publicly supplied

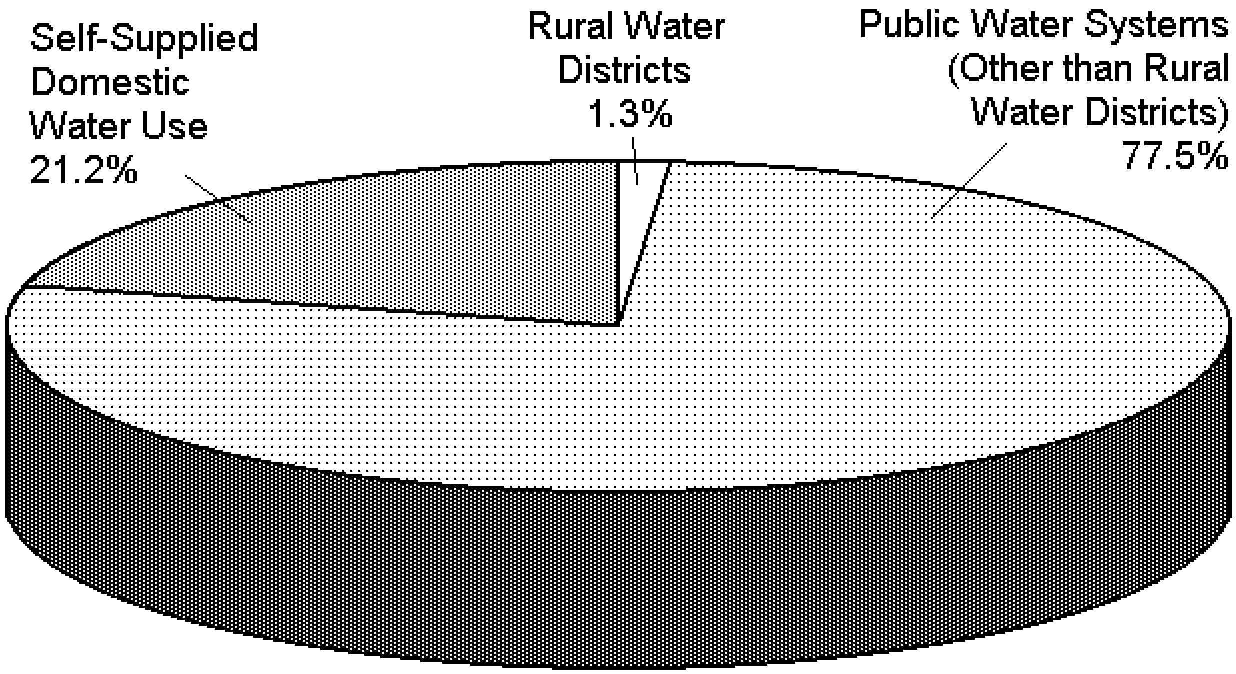


Figure 4. Percentage of domestic water use by category, 1995.

water in Nebraska and virtually all self-supplied domestic water. Part of the Omaha area (Douglas and Washington counties) accounted for more than 99% of publicly supplied water drawn from surface supplies. Therefore, groundwater is overwhelmingly the source for small community supply systems. Nebraska has about 1,340 public water supply systems (NPWSP, 1997). A public water system is defined as one that has at least 15 service connections or that regularly serves at least 25 individuals.

There are three types of public water systems (figure 5). Community water supply systems serve at least 15 service connections used by year-round residents or regularly serve 25 year-round residents. They include not only city or village systems, but such entities as rural water districts, sanitary improvement districts, and systems serving mobile home parks. In 1997 there were 621 community water supply systems in Nebraska, of which 608 serve populations of fewer than 10,000 (NPWSP 1997). It should be noted that in places this report refers specifically to “small city, village, and/or rural water systems,” rather than “small community systems.” This is because some types of data could not be obtained for *all* community water systems.

The other two types of public water systems are transient and nontransient noncommunity water supply systems. Like community systems, these either have at least 15 service connections or regularly serve at least 25 individuals, but, for the most part, they are not serving year-round residents. A noncommunity system that serves at least 25 regular, repeat users during at least 6 months per year is a nontransient noncommunity system (185 in Nebraska). One that has fewer than 25 regular, repeat users is a transient noncommunity system (534 in Nebraska). A nontransient noncommunity system, for example, might serve a business

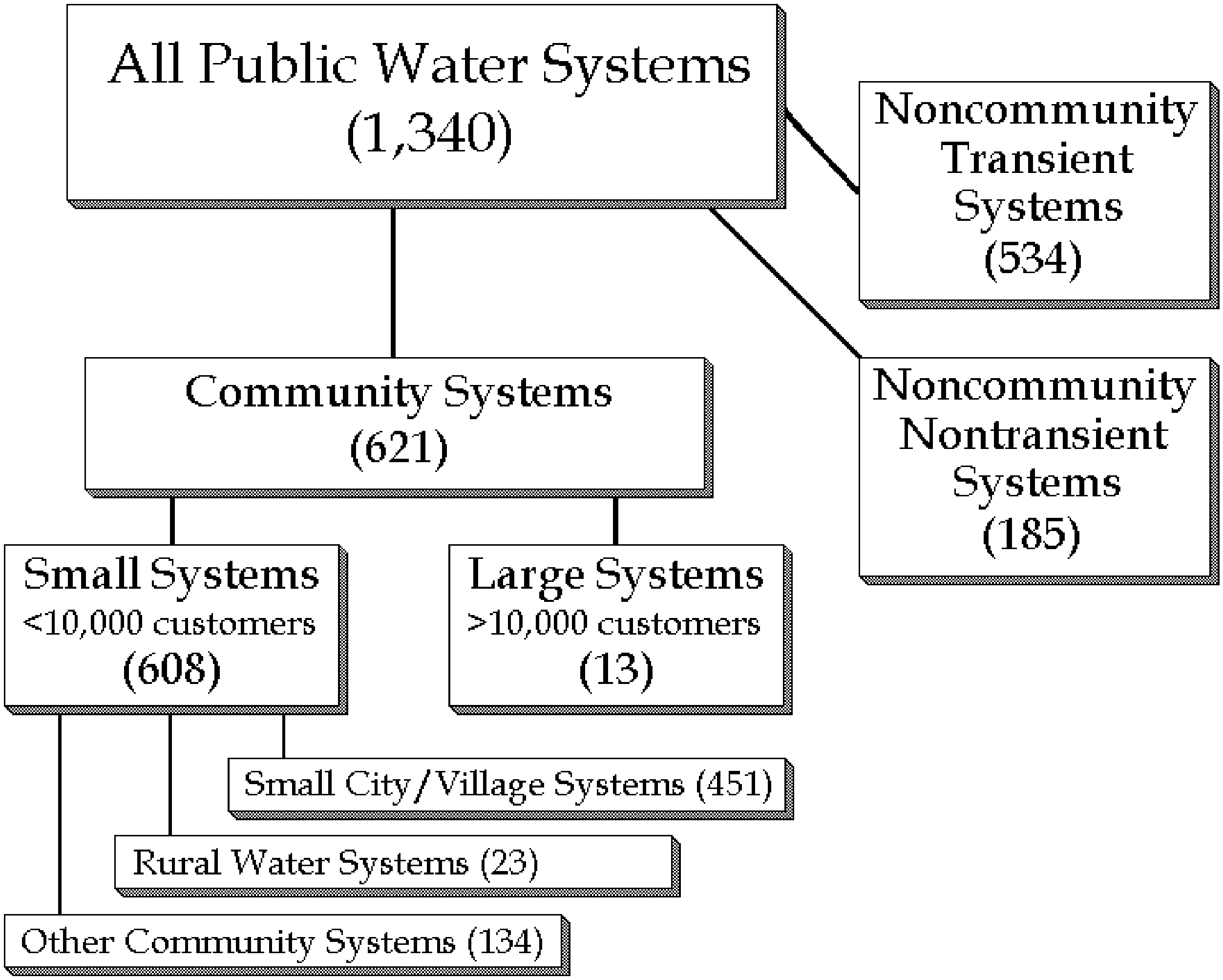


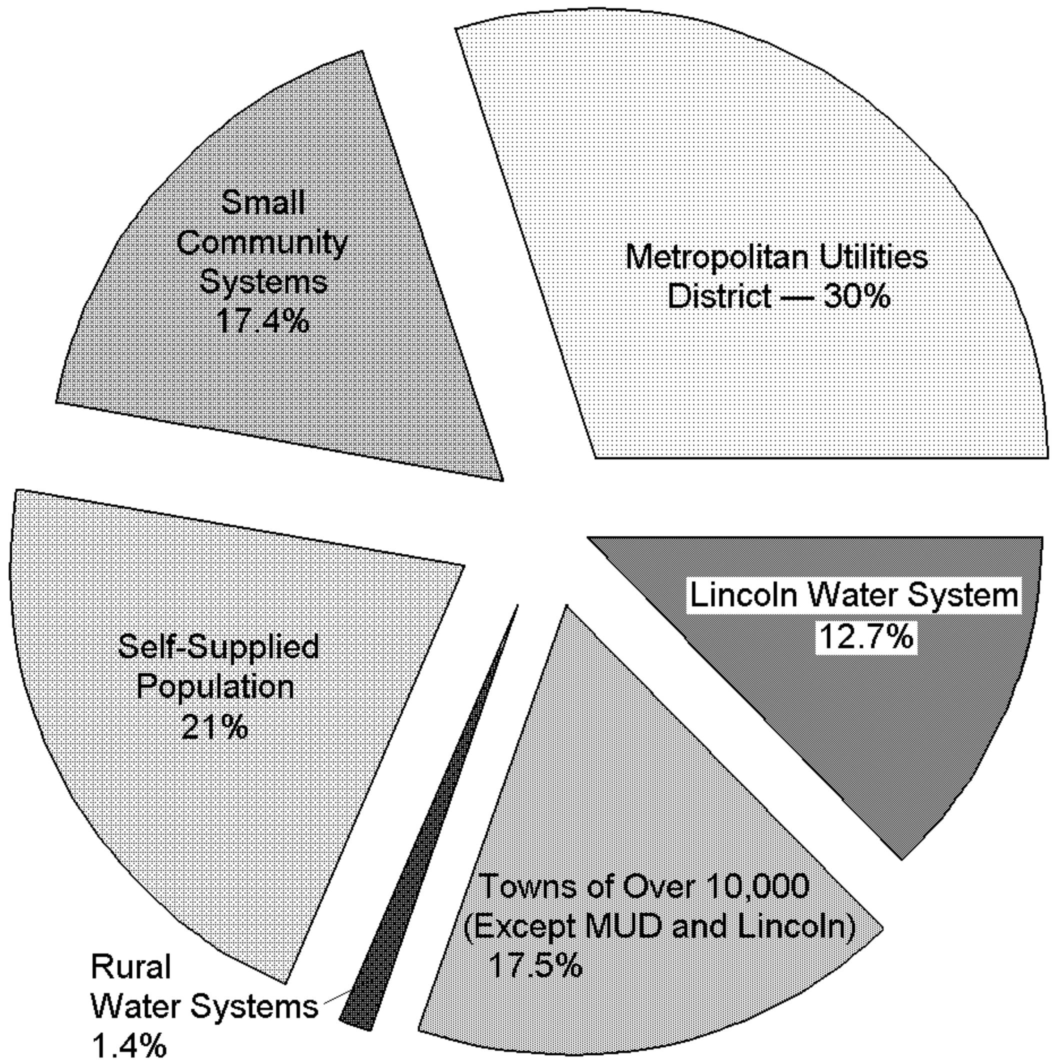
Figure 5. Types of public water systems in Nebraska and the number of systems in each category, as of 1997. (Source: NPWSP, 1997, and HHSS files.)

with more than 25 employees or a rural school with more than 25 students. A transient noncommunity system might serve a roadside café, a campground, or a highway rest area.

The combined total of people served by community water systems in incorporated towns below 10,000 (excluding small towns served by Omaha's Metropolitan Utilities District), by nonmunicipal community systems, and by rural systems equals about 19% of Nebraska's population (figure 6). However, those users account for all but 13 of Nebraska's 621 community water systems.

Rural water systems are a special type of community water supply system that in 1995 served about 23,000 Nebraskans or about 1.4% of the state's population. The 23 systems are found primarily in the eastern part of the state, where availability of groundwater is less uniform. Service areas of the rural water systems cover about 7% of the state's area, but these systems

Figure 6.
Nebraska Water Service Providers by Estimated Percentage of Population Served — 1996



Sources: U.S. Bureau of the Census population figures released March 1998
Burns McDonnell, Inc., Platte River West Water Production Facilities Draft EIS, 1998, prepared for Metropolitan Utilities District and U.S. Army Corps of Engineers, p. 1-2 (for MUD service area population estimates)
Estimated Water Use in Nebraska; 1995; Nebraska Natural Resources Commission (for self-supplied population estimate). Note: the 21% figure for self-supplied population is arguable. 1990 Census of Housing reported that just under 17% of housing units had sources other than public or private company supplies.
Rural water system and self-supplied population figures use 1995 estimates.
Percentage for small community systems was derived as a remainder after determining numbers for other categories. Actual estimated population of towns of under 10,000 in 1996 was 388,128 or 23.5% of the state's population.

delivered an estimated 918 million gallons of water in 1995—less than 1% of the state's publicly supplied water use (NNRC file estimates 1998). Rural system service areas are shown in figure 7. Since formation of Nebraska's Natural Resources Districts (NRDs) in 1972, new rural water systems have come under their authority, but there is no requirement for the previously existing water systems to merge with the NRDs. NRDs currently operate nine domestic water supply systems serving more than 3,000 customers and nine small communities.

Not all of Nebraska's small towns have public water supply systems. Keefer and Lamberty (1995) analyzed drinking water sources and distribution systems for 521 Nebraska towns and found that 59 towns had no public drinking water system. They also found that 282 of the communities had multiple wells but no common distribution system, 78 communities had single wells, and only 55 communities had multiple wells on a common distribution system.

SELF-SUPPLIED DOMESTIC WATER USE

Self-supplied domestic water served about 346,400 Nebraskans in 1995—about 21% of the state's population—according to Nebraska Natural Resources Commission estimates (NNRC, 1998). Gosselin et al. (1996) found that in 1990 domestic wells supplied water to 110,754 Nebraska households out of the state's estimated 660,621 households and that an estimated average of 3 people used each well. A separate source, the 1990 Census of Housing, indicated that individual domestic water wells supplied water to about 17% of Nebraska households in 1990 (figure 8). As previously noted, as of 1995, 59 Nebraska towns had no public water supply systems.

IMPACT OF NITRATE ON SMALL PUBLIC WATER SYSTEMS

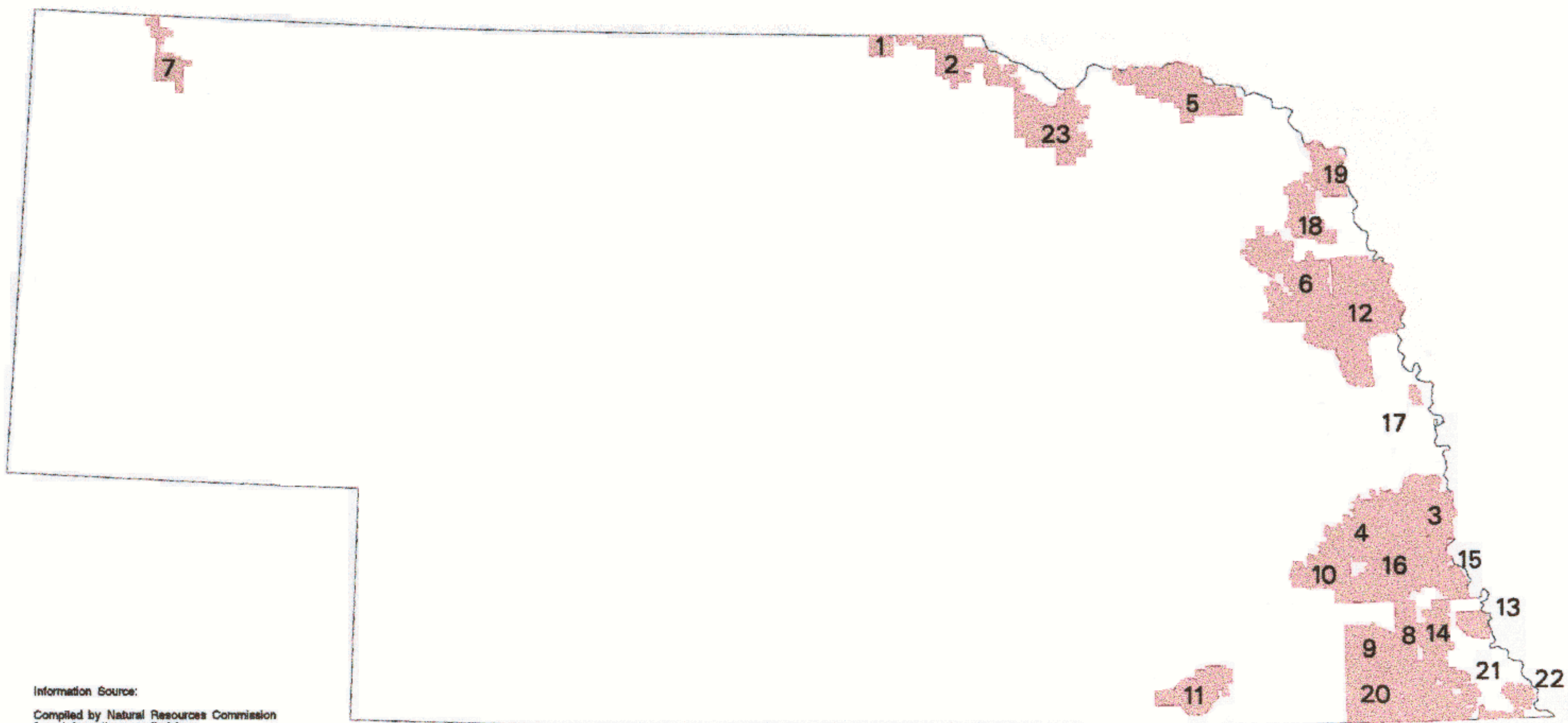
According to the computerized records of Nebraska's Health and Human Services System (HHSS), the state had 1,340 public water supply systems as of 1997. Thirteen of these were large municipal systems that each served more than 10,000 people; those systems are not considered here. Of the remaining 1,327 systems, 608 were classified as small community systems, and 719 were noncommunity systems (which were further subdivided into transient and nontransient noncommunity systems). Of the 608 community water systems, 451 were small city and village systems.

Available records indicate that from the 1960s through 1998, 168 (37%) of the 451 small city and village systems have produced one or more water samples that exceeded the U.S. Environmental Protection Agency's (EPA) MCL for nitrate nitrogen (10 mg/L). Such samples may reflect high nitrogen levels throughout the system or just in individual source wells or points of entry. At least 296 (66%) of these systems have had a reading over 5 mg/L. If only data collected from 1981 through 1998 are analyzed, the figures change as follows: during that period, 129 systems (29%) had a reading over 10 mg/L, 122 systems (27%) had a highest reading between 5 and 10 mg/L, and 200 systems (44%) had highest readings less than 5 mg/L. Far

Figure 7
Nebraska Rural Water Systems — November 1995

SCALE 1:3,000,000

1. Boyd County RWD1
2. Boyd County RWD2
3. Cass County RWD1
4. Cass County RWD2
5. Cedar-Knox RWD
6. Cuming County RWD1
7. Dawes County RWD1
8. Johnson County RWD1 East
9. Johnson County RWD1 West
10. Lancaster County RWD1
11. Little Blue NRD RWD1
12. Logan East RWD
13. Nemaha County RWD1
14. Nemaha County RWD2
15. Otoe County RWD1
16. Otoe County RWD3
17. Papio-Missouri River NRD RWD1
18. Papio-Missouri River NRD RWD2
19. Papio-Missouri River NRD RWD3
20. Pawnee County RWD1
21. Richardson County RWD1
22. Richardson County RWD2
23. West Knox RWD



Information Source:

Compiled by Natural Resources Commission
from information supplied by :
USDA Rural Development
Nebraska Rural Water Association
Selected Natural Resources Districts
Selected Rural Water Districts
Produced By - Natural Resources Commission
GIS Process - ARC/INFO
Processed - April 1996

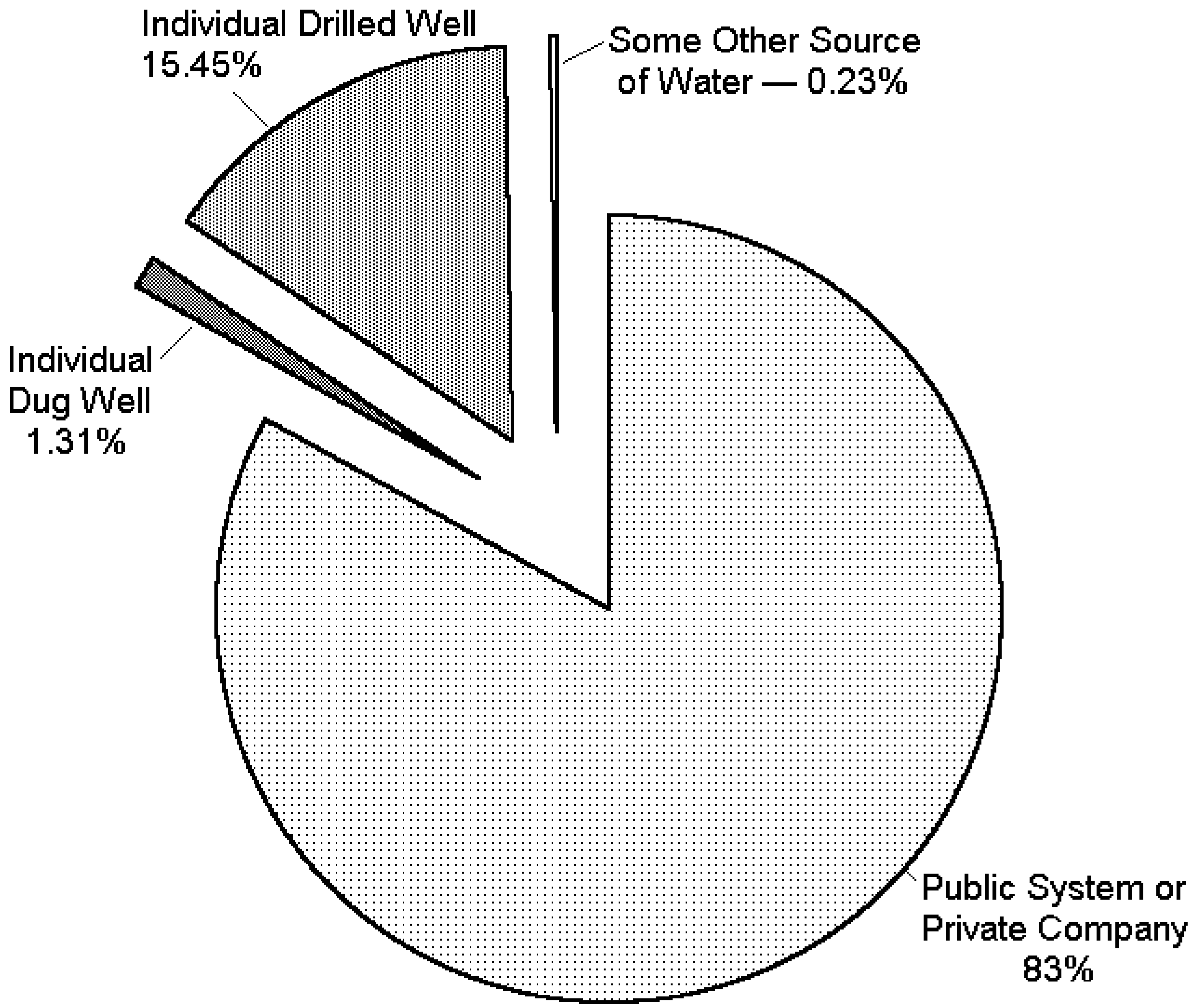


Figure 8. Water sources for Nebraska housing units, 1990. Source: U.S. Bureau of the Census, 1990 Census of Housing, Detailed Housing Characteristics, Nebraska, 1990, CH-2-29.

more samples have been collected in recent years than in the period before 1984. Further information on community nitrate records is found in the "Nitrate Data Analysis" section of this report.

Since 1981, the operators of small city, village, and rural systems have built or are in the process of building at least 59 nitrate-related projects, with a total estimated final cost of over $24 million, according to data compiled for this report. The water systems that have undertaken these projects serve a combined population of about 60,000 people, and so the per capita cost to those populations has been more than $400 per person.

In 1995, the EPA estimated Nebraska's 20-year need for drinking water infrastructure at almost $953 million, and small systems (serving fewer than 3,000 people apiece) accounted for $472 million of that need. It estimated expenditures required for compliance with the Safe

Drinking Water Act at over $184 million; however, only $8.4 million of this amount was related to meeting nitrate standards. Given spending levels indicated in this report it appears the $8.4 million 20-year need ascribed to nitrate may be an underestimate.

The most common major infrastructure expenditure undertaken by small communities to remediate a nitrate problem is for drilling a new well and for constructing transmission lines from the well. If there is no good source of supply in the immediate area, costs can rise as longer transmission lines are needed. In a few cases communities may go to the large expense of building a treatment plant.

Among the 719 noncommunity systems, about 79 (11%) are known to have had a least one nitrate nitrogen sample in excess of the 10-mg/L MCL, and at least 154 (21%) have had a reading over 5 mg/L. There are fewer records available for noncommunity systems, though, which may explain why they appear to have a lower percentage of nitrate problems. A further indication of the extent of nitrate contamination in rural Nebraska comes from a statewide survey by the Nebraska Department of Health and the University of Nebraska, which sampled 1,808 private domestic wells in 1994–95 and found that approximately 19% of the wells had nitrate levels above the MCL (Gosselin et al., 1996, 1997).

PUBLIC AND PRIVATE DOMESTIC WATER SYSTEM WELL SITING AND CONSTRUCTION

The HHSS has requirements for monitoring and operation of public water supply wells and for siting, design, and construction of new public water wells. These include title 179 for public systems and title 178 for private systems. Nevertheless, in many cases, construction, hydrologic, and site factors contribute to nitrate problems in older wells. A well that is poorly sited, poorly constructed, or too shallow may be susceptible to small point sources of contamination that don’t affect a large area. Old private domestic wells are most likely to be affected by construction and siting problems. Large-diameter dug private wells in eastern Nebraska are especially subject to problems. Because those wells do not have either a pipe or a sanitary seal, they are at greater risk of point-source contamination from the surface. In many instances, increased well depth or grouting could address the problem. Private domestic wells that do have nitrate problems should also be checked for pesticides.

Trying to determine whether well siting or an abundance of nitrate sources is the primary cause of nitrate contamination is a difficult and perhaps subjective exercise. Theoretically, a shallow, poorly sited well might be drawing from the only contaminated level of the only contaminated part of a large aquifer. On the other hand, in heavily contaminated areas or areas with a limited aquifer, it may be impossible to find uncontaminated groundwater anywhere in the vicinity. In between those two extremes is a large array of potential relations between well-site characteristics and the prevalence of nitrate sources. In places where nitrate sources have increased, old, poorly sited wells might be affected earliest and most seriously. The study team did not examine the age, depth, or construction of the public water supply wells that had high nitrate readings and were replaced or relegated to backup status.

Gosselin et al. (1996, 1997) identified several factors that could influence the occurrence of contaminants in domestic wells. Those factors generally are also applicable to public water wells and are worth repeating here. Gosselin et al. divided these factors into three groups: "(1) well construction factors, which include casing type, installation date (age), diameter, well completed in or out of pit (i.e., top of well above the ground or in an excavated pit below the land surface), sanitary seal, and well type; (2) distance factors, which include distance to cesspool, septic systems, waste lagoons, barnyards, pasture, and cropland; and (3) hydrogeologic and site factors, which include well depth, depth to water, landscape and soil characteristics, and agricultural chemical use on premises."

ECONOMIC COSTS OF ADDRESSING NITRATE PROBLEMS IN PUBLIC WATER SUPPLIES

Data compiled for this report indicate that, from January 1981 through February 1998, Nebraska small cities and villages had built or were in the process of building nitrate-related projects with a total estimated final cost of more than $24 million. In some ways this figure is overstated, because nitrate contamination was only one of the reasons some of the projects were built. It should be noted that costs for monitoring and for operation and maintenance of treatment facilities are not included in this figure. If the total amount is adjusted into 1997 dollars it becomes $28 million. The 59 small cities, villages, and rural water systems had a combined population of about 60,000 and, on that basis, will have paid an average of more than $400 per capita for the improvements. What entity actually pays for improvements and where the funds originate can vary between projects.

In comparison to overall water system expenditures or to the water system infrastructure needs projected by the EPA (1997), this number is small. Figures compiled for this report indicate that in 1996 and 1997 combined, nitrate-related water system projects accounted for more than $3.5 million[1] out of an estimated cost of nearly $40 million for all small community water project construction (including water main construction) approved by HHSS. The need to address nitrate contamination was a major factor for 16 of the 55 wells approved for construction. The EPA (1997) has estimated Nebraska's current needs for nitrate-standard-related infrastructure needs at $8.4 million, but this compares to $184 million needed for Safe Drinking Water Act compliance and an overall need of almost $953 million for infrastructure improvement over 20 years. At $472 million, small systems (serving fewer than 3,300 in the EPA study) accounted for nearly half of the 20-year statewide infrastructure need.

Nitrate violations accounted for nearly half (34 of 69) of the water quality violation administrative orders (AOs) issued by HHSS from 1991 through 1997. However, recent changes in EPA standards may lead to an increase in AOs based on other drinking water constituents and

[1] This figure should be used with caution. Community survey estimates and other cost projections for the same 12 approved projects indicate a likely cost of more than $6.5 million. Three other projects already underway but not included on the HHSS lists would bring the total to about $8.3 million. These higher figures are reflected in figure 10.

properties and, hence, nitrate will account for a relatively smaller proportion of these, even if the frequency of nitrate-related AOs remains the same. As of March 1999, for instance, 56 Nebraska community water systems had exceeded the EPA action level for copper (1.3 mg/L). This extreme increase in the number of communities at or above the action level is a result of EPA's adoption of new requirements; not of any sudden regional decline in water quality. It seems likely that the new requirements and other potential requirements, such as mandatory disinfection, could result in substantially increased infrastructure costs for Nebraska's small communities.

Table 2 shows the number of small city and village water systems that have undertaken nitrate-related projects, and table 3 summarizes the costs of these projects. Table 4 lists communities that have planned, undertaken, or completed nitrate-remediation projects between 1981 and 1997 and the approximate cost of each project. These tables are based upon research of HHSS files, Community Development block grant files, and a survey of communities thought to have made nitrate-related system improvements. Figure 9 shows the locations of these

Table 2
Nitrate MCL Violations and Infrastructure Improvements Since 1981 in Nebraska's Small City and Village Public Water Supply Systems

[Includes only data reported from 1981 through February 1998 for small city and village systems serving fewer than 10,000 people]

Description	Number of systems	Comments
Total number of small city and village systems serving <10,000	451	Depends on date surveyed
No nitrate reading above 5 mg/L	155	These data from HHSS paper and electronic files for the period from 1981 through December 1998
Highest nitrate reading in range of 5–10 mg/L	128	
At least one nitrate reading >10 mg/L	168	
Received nitrate-related AO (all community systems)[1]	62	Total of 74 AOs received by these systems, of which 67 went to small city and village systems
Received nitrate-related AO and made related infrastructure improvements (all community systems)[1]	41	Includes 5 small community systems not related to any city, village, or rural water system
Received nitrate-related AO but not known to have made related infrastructure improvements (all community systems)[1]	21	Only nine of these were city, village, or rural water systems
City, village, and rural systems that had no nitrate-related AOs but apparently made nitrate-related infrastructure improvements	23	Includes only city, village, or rural water systems
Total city, village, and rural systems that made nitrate-related improvements	59	

[1] Small city and village systems are a portion of the approximately 605 community water systems.

Table 3
Nitrate-Related Infrastructure Expenditures Since 1981 by Nebraska's Small City, Village, and Rural Water Systems

[Includes data reported from 1981 through April 1998 for systems serving fewer than 10,000 people. Also includes projected costs of projects underway]

Description	Approximate cost
Expenditures by small cities and villages that received an AO	$11,283,298
Total expenditures	$24,667,600
Average per capita cost (based on 60,206 people [1996 estimate] served by the 59 systems that made improvements)	$410
Inflation-adjusted total expenditures (constant 1997 dollars)	$28,056,574

Additional note: Nitrate-related drinking water projects accounted for 8.8% of the overall estimated cost of water projects approved in 1996 and 1997.

communities. Figure 10 charts approximate expenditures for nitrate-related projects by year since 1981. Attachment A contains further information on the derivation of cost estimates.

Significant maintenance costs for communities that built water treatment systems in response to nitrate problems would push overall cost figures higher. These same communities also face increased monitoring costs. Any community that exceeds a 5 mg/L monitoring trigger at its point of entry must continue to sample quarterly until readings have been under 8 mg/L for four consecutive quarters. A sample analyzed for nitrate by the HHSS lab cost $18.10 in January 1998.

The most significant single cost impact from nitrates may come about if a community needs to treat its water. Keefer and Lamberty (1995) noted that, as of 1995, "only 44 of the 425 towns with wells treat their drinking water; 28 disinfect, 5 treat for nitrates, and 21 remove iron and manganese." Most of those towns had multiple wells but no common distribution system. The costs of going to treatment, whether for nitrate or other causes, can be very high for such communities, much higher than the cost of drilling a new well.

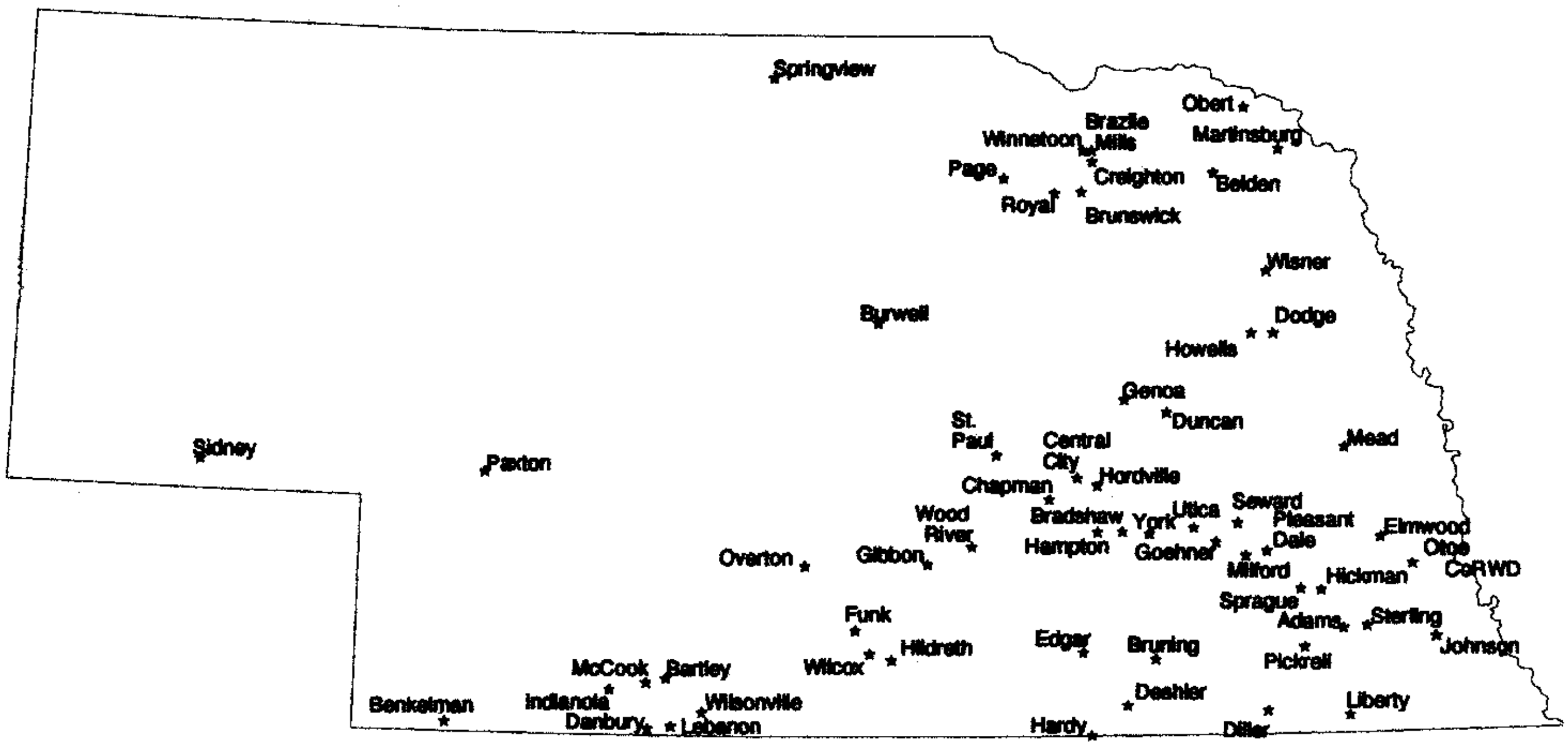
Nitrates are likely to continue to be a significant issue to communities. The Nebraska Mandates Management Initiative provides a specific case in point. This program, administered by DEQ, has delivered direct technical assistance on infrastructure problems to a range of communities. Of the 83 communities that participated fully in the program between May 1995 and January 1998, 42 identified nitrate concerns as a significant issue. Sixteen of these communities had received an AO for nitrate at some point since 1981 (DEQ 1998).

Although the infrastructure costs discussed above are significant, they were not all paid by the water systems or consumers. Community development block grants and grants and loans from the U.S. Department of Agriculture accounted for much of that cost. An analysis of water rates for most of the affected communities revealed that communities that had made infrastructure improvements to address nitrate problems had only marginally higher rates than other communities (table 5).

Figure 9

SMALL CITIES OR VILLAGES OF 10,000 OR LESS
Which had Major Nitrate Related Community Drinking Water System Infrastructure Projects Completed or Underway 1981 - 1997

(includes projects approved in 1997 but for which construction may not begin until later)



Information Sources:

Nebraska Health and Human Services System
Public Water System Files
Nebraska Department of Economic Development
Community Development Block Grant Files
Survey of 92 Nebraska Communities by Nebraska
Natural Resources Commission
Produced By - Natural Resources Commission
Cities - TIGER Files
GIS Process - ARC/INFO
Processed - August 1998

*Communities included, with a few exceptions, either responded to a survey or had received an administrative order and subsequently under took improvements. In some instance communities may have simultaneously undertaken other drinking water infrastructure improvements or improved a system more than was needed to address the nitrate problem. Insufficient information was available to exclude those types of expenditures from this table. Community water systems other than cities or villages are not included on this map.

Table 4. Estimated Cost of Nitrate-Related Infrastructure Completed or Under Way by Small Cities, Village, and Rural Water Systems 1981–early 1998

[Compiled from a survey conducted for this study and from the records of the Nebraska Health and Human Services System and the Community Development Block Grant Program. Includes projects submitted for HHSS review in 1997 or early 1998 but for which actual construction may not have begun. Surveys were sent to 87 small city or village water systems which (1) had had a nitrate sample over 5 mg/L or a nitrate-related administrative order since 1981 and (2) were identified as having undertaken a subsequent water supply project that may have been related to nitrate. Responses came back from 79 small cities or villages. A final list was developed that included 59 communities identified as having made nitrate-related water system expenditures. That list includes five villages that were unconfirmed (four of which made improvements subsequent to receiving an administrative order). It also includes one village that did not receive a survey but was installing its first water system. Three villages that had received no administrative order and did not respond were excluded from the final list. The listed sources of cost data do not denote funding sources. While figures used are not exact, in the composite they provide a rough estimate of total project costs]

Record of Administrative Order	HHSS Review Year[1]	Completion Year	Name of System	Population (1996)	Cost (dollars)	Source of Cost Data[2]	Cost per Capita (dollars)	ENR Index,[3] start year +1	Cost in 1997 Dollars
AO	1989	1991	Adams [4]	476	399,000	CDGB/Town	838.24	4732	491,246
AO	1987	1989	Bartley	333	106,072	Town	318.53	4519	136,750
AO	1996		Bazile Mills	35	118,500	HHSS/Town	3,385.71	5826	118,500
AO	1987		Belden	146	105,000	HHSS/Town	719.18	4519	135,368
	1996		Benkleman [5]	1,071	705,491	Town	658.72	5826	705,491
AO	1988	1992	Bradshaw (unconfirmed) [6]	343	381,600	CDGB	1,112.54	4615	481,734
AO		1982	Bruning	324	200,000	Town	617.28	3535	329,618
AO		1998	Brunswick	170	503,900	CDGB/Town	2,964.12	5826	503,900
AO	1985	1988	Burwell	1,250	240,000	Town	192.00	4295	325,551
	1997		Central City	2,906	107,000	HHSS/Town	36.82	5826	107,000
	1997		Chapman [7]	296	1,245,600	CDGB	4,208.11	5826	1,245,600
AO	1989	1993	Creighton [4, 8]	1,149	1,035,000	CDGB/Town	900.78	4732	1,274,284
AO		1984	Danbury	107	176,000	CDGB/Town	1,644.86	4066	252,183
	1997		Deshler	833	200,000	Town	240.10	5826	200,000
	1990		Diller [9]	297	260,000	Town	875.42	4835	313,291
AO	1985	1988	Dodge	686	92,083	Town	134.23	4295	124,907
AO	1984		Duncan (unconfirmed) [6]	372	148,500	CDGB	399.19	4195	206,236
AO	1989	1992	Edgar (unconfirmed) [6]	636	168,800	CDGB	265.41	4732	207,825
AO	1990		Elmwood [4]	611	486,948	CDGB/Town	796.97	4835	586,755
AO	1990	1992	Funk	202	422,300	CDGB/Town	2,090.59	4835	508,856
	1986		Genoa	1,069	499,500	CDGB/Town	467.26	4406	660,483
AO	1996		Gibbon	1,473	875,605	Town	594.44	5826	875,605
AO	1986	1989	Goehner	192	159,500	CDGB/Town	830.73	4406	210,905
AO	1989	1992	Hampton	418	409,400	CDGB/Town	979.43	4732	504,050
	1992		Hardy [4]	199	396,200	CDGB/Town	1,990.95	5210	443,044
AO	1986	1988	Hickman	1,150	297,700	CDGB/Town	258.87	4406	393,645
AO	1986		Hildreth (unconfirmed) [6]	361	92,000		254.85	4406	121,650

	1997		Hordville [10]	168	245,000	HHSS/Town	1,458.33	5826	245,000
	1987	1992	Howells [11]	687	665,000	CDGB	967.98	4519	857,333
AO	1985	1989	Indianola	630	309,896	Town	491.90	4295	420,362
AO	1985	1988	Johnson	333	205,312	Town	616.55	4295	278,498
AO		1985	Lebanon	72	222,000	CDGB/Town	3,083.33	3825	338,136
AO	1985		Liberty	75	52,650	HHSS/Town	702.00	4295	71,418
AO	1986	1988	Martinsburg	93	32,000	CDGB/Town	344.09	4406	42,313
AO	1988	1995	McCook	7,926	780,000	CDGB/Town	98.41	4615	984,676
	1992		Mead	535	70,000	HHSS/Town	130.84	5210	78,276
AO	1986	1988	Milford	1,989	235,800		122.62	4406	322,485
	1990	1992	Obert	38	40,000	Town	1,052.63	4835	48,199
	1996		Otoe Co. RWD	2,294	255,290	HHSS/Town	111.29	5826	255,290
	1992		Overton [12]	766	422,800	HHSS	551.96	5210	472,789
AO	1992	1994	Page [4]	182	380,000	Town	2,087.91	5210	424,929
AO		1998	Paxton	523	1,164,000	Town	2,225.62	5826	1,164,000
AO	1991		Pickrell (unconfirmed) [6]	205	72,440	HHSS	353.37	4985	84,661
	1993		Pleasant Dale	250	116,000	CDGB	464.00	5408	124,966
	1993		Rockville [13]	115	356,586	HHSS	3,100.75	5408	384,148
AO	1993		Royal	75	50,000	CDGB	666.67	5408	53,865
	1996		*Seward (questionable)* [14]	*6,093*	*1,928,000*	*HHSS/Town*	*316.43*	*5826*	*1,928,000*
	1992		Sidney	6,128	1,500,000	HHSS/Town	244.78	5210	1,677,351
AO	1985		Sprague	150	85,000	Town	566.67	4295	115,299
	1997		Springview [15]	297	435,328	Town	1,465.75	5826	435,328
	1995		St. Paul [4]	2,181	3,250,874	Town	1,490.54	5620	3,370,034
	1989		Sterling	449	69,800		155.46	4732	85,937
AO	1986		Utica	752	115,708	CDGB/Town	153.87	4406	152,999
AO	1989		Wilcox	359	297,000	CDGB/Town	827.30	4732	365,664
AO	1988		Wilsonville	140	378,600	CDGB/Town	2,704.29	4615	477,947
	1983		Winnetoon	60	95,700	CDGB/Town	1,595.00	4146	134,479
	1996		Wisner	133	154,133	Town	1,158.89	5826	154,133
AO	1985	1987	Wood River	1,257	562,900	CDGB	447.81	4295	763,552
	1996		York	8,146	280,000	HHSS/Town	34.37	5826	280,000
			TOTAL	60,091	24,667,600		409.72		28,056,574

See footnotes on following page.

Footnotes for table 4.

[1] Some projects had more than one review year. In those cases the latest one is given.
[2] CDGB, Community Development Block Grant files. HHSS, Nebraska Health and Human Services System files.
[3] Engineering News Record cost index for the year following the project's starting year.
[4] Built a treatment facility.
[5] Survey response noted "nitrate was one of the reasons—however, the quantity of water that could be pumped from existing wells was probably a more important factor."
[6] Not confirmed, but town did receive an administrative order for nitrates and made improvements shortly thereafter.
[7] Town had no community water system. Installation is occurring in part due to nitrate in individual wells. No survey was sent to this town.
[8] Creighton survey response specifically noted that nitrate was the only reason for the treatment plant.
[9] Telephone follow-up survey of Diller indicated that nitrate was a contributing factor, as well as manganese and pumping clay.
[10] Hordville expenses were first for carbon tetrachloride problem, but then for nitrate problem also. Survey response indicated total cost would likely be considerably more than $245,000, but overall figure is not available.
[11] Howells project not yet complete and town survey response noted final cost was expected to be $780,000 to $850,000.
[12] Overton indicated well replacement around 1982 as well, also due to nitrate. Also storage was improved at that time.
[13] Town not contacted. However, town installed water system due to nitrate in individual wells.
[14] Seward survey response also noted "projected water treatment at $4,500,000." Only $1,928,000 project submittal to HHSS in 1996 was used in this table. However, as of June 1999, action on a treatment system was postponed. It is therefore questionable whether this entry should be included in this table. Nevertheless, it has been included here and in the summary statistics.
[15] Nitrate only one factor. Town put in extensive mains, hydrants and other infrastructure as well.

In addition to the small city, village and rural water systems included in this table, some evidence was found that at least an additional 5 community water systems that received administrative orders and were not operated by cities or villages made improvements with a cost of $176,542 over the period. Those amounts are not included in the totals in this table.

No Survey Response – Not Included

It is not known whether the following communities made infrastructure improvements in response to nitrate. They are therefore not included in the summary statistics. All of these communities had nitrate reading above 7 mg/L and later made system improvements, after which nitrate levels dropped. However, none of the communities received administrative orders. In the survey of communities with similar characteristics, a majority of the changes were not nitrate related. No survey response was received from these towns.

Community	Year of Project Initiation	Cost
Cody	1983	$375,850
Elk Creek	1997	$27,507
Fullerton	1994	$18,000

Unsurveyed Nonmunicipal Systems

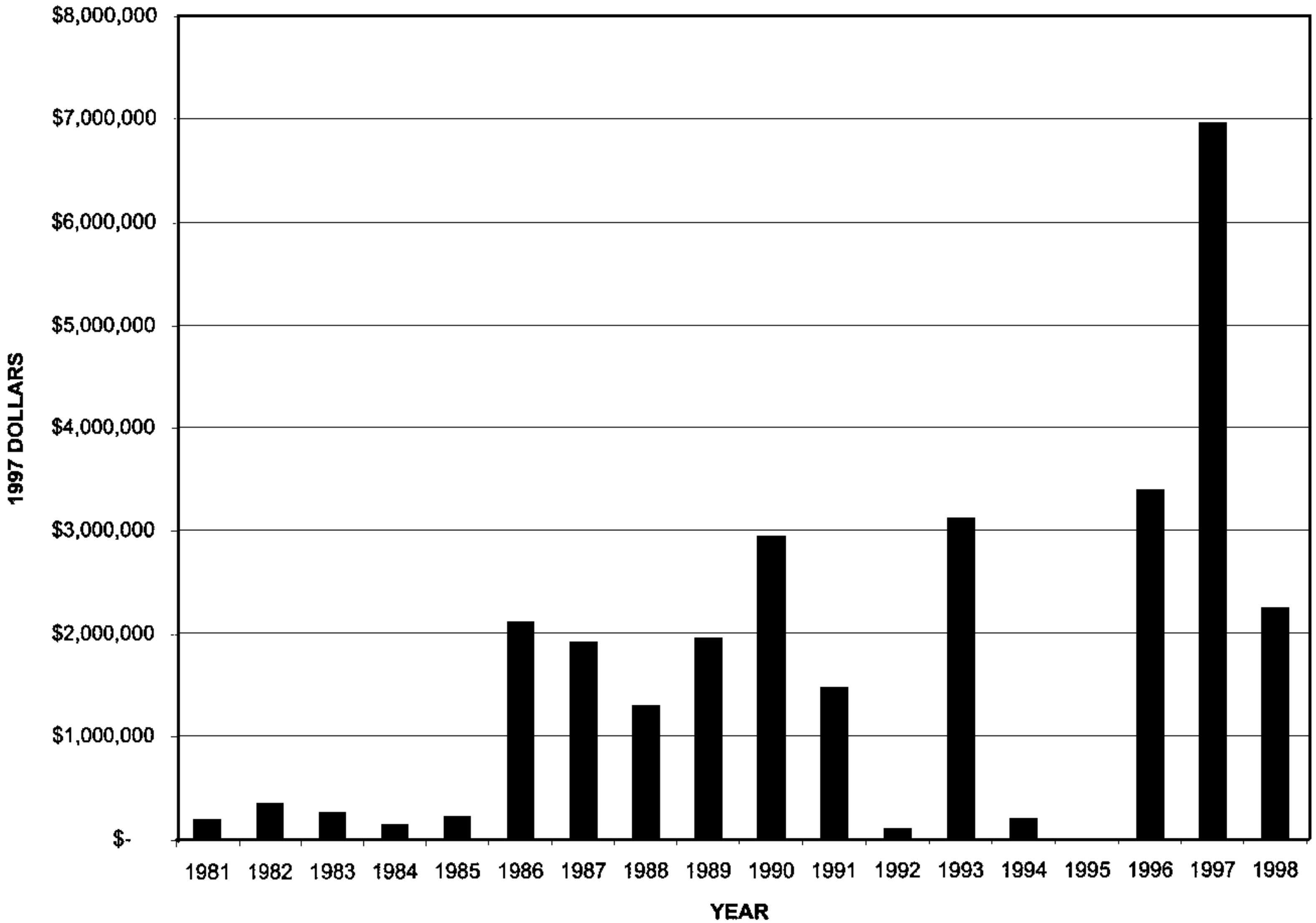
West Park Plaza	$20,000
Mobile Manor	$18,000
Green Acres Mobile	$5,600

Sources:

Nebraska Health and Human Services System – Public Water System Files (HHSS)
Nebraska Department of Economic Development – Community Development Block Grant Files (CDBG)
Natural Resources Commission Survey of 92 Selected Small City and Village Water Systems
Table Compiled by Nebraska Natural Resources Commission

Figure 10

Rough Adjusted Annual Cost of Nitrate Related Projects by Small City, Village and Rural Water Systems. 1982-1998 includes projects reviewed by NHHS but not yet built.*



***Assumes all project costs come in the year after project review by NHHS or in few cases in year prior to project completion.**

Table 5
Average Monthly Water Rates in Small Cities and Villages That Made Nitrate-Related Water System Improvements, Compared to Statewide Average

Rate basis	"Improved" systems	Statewide average
Metered:		
Base rate	$8.14	$7.51
Overage charge (per 1,000 gal.)	$0.93	$0.92
Flat Rate	$12.54	$10.15

Source: Nebraska Rural Water Association, 1997, 1997 rate survey ("Metered water rates" and "Flat water rates" sections) and HHSS files (per capita average). Comparison included 31 of the 58 communities that made nitrate-related improvements (11 flat rate and 21 unmetered).

ECONOMIC AND SOCIAL COSTS TO SELF-SUPPLIED DOMESTIC USERS

Customers of public water supply systems are not the only people affected by the costs of responding to nitrate-related contamination. Gosselin et al. (1997) sampled 1,808 private domestic wells in 1994–95 and found that approximately 19% of the wells sampled were over the Federal MCL for nitrate nitrogen. In 1990, an estimated 110,754 households were supplied by individual domestic water wells (Gosselin et al. 1997). The NNRC (1998) estimates that about 21% of Nebraskans were served by self-supplied domestic water in 1995. Because the wells selected for the Gosselin et al. study were from residences where occupants were actively engaged in farming and/or occupied at least 6 acres of land, the samples may not accurately reflect all private wells. In general, it seems that smaller, nonagricultural plots are more likely to have newer wells or to have wells that had to be improved during a change of ownership. However, they may also be in more heavily populated areas and possibly more subject to septic tank contamination. Private well use is expanding in the rural areas around Lincoln, Omaha, and Grand Island.

Whatever conclusions are drawn about the level of health risk posed by the nitrate levels reported by Gosselin et al. (1997), their findings do indicate the potential for nitrate-related expenditures by owners of some private domestic wells. Increased well depth and grouting are a likely solution to many domestic well problems. However, the cost of deepening a single private domestic well averages in the range of $1,200 to $1,500, and the cost of replacing a well, including pump and piping, averages in the range of $3,000 to $4,000. Given those figures, the costs of reducing nitrate concentrations in all wells to less than 10 mg/L could be very high. However, costs can vary depending upon well depth and upon whether deepening is the only action required.

It is likely that many individual well owners would seek to avoid such an expense. Inasmuch as the nitrate MCL is set at a level believed to protect the health of pregnant women and infants, some families that do not include such high-risk individuals might believe they can afford to exceed the MCL. Some may also find other options, such as point-of-use treatment, more affordable. No survey was done of how many rural domestic well owners with high nitrates are using point-of-use treatment. Alternatives for self-supplied rural domestic water users are discussed elsewhere in this report.

Another problem related to reducing nitrate levels in private wells is the difficulty of even identifying which wells need treatment. The percent of rural domestic water users who test their water and have an idea of nitrate levels is not known. In a nine-state 1994 survey of 5,520 private well users by the Centers for Disease Control (GAO, 1997, p. 20), 44% of those responding said their wells had never been tested for contamination, 44% said theirs had been, and 11% did not know. This survey included Nebraska.

As of 1995, there were 59 Nebraska towns that had no public water systems. In addition, many unincorporated developments lack public water supplies. The proximity of septic tanks and wells in a concentrated space is of concern in some of these areas. In many cases the older domestic wells may not be as well sited or constructed as a community well would be. At least one small town was installing its first community water system as this report was being written. Around the state are other concentrations of residences without a public water supply that may decide to build community water systems.

OTHER SOCIOECONOMIC FACTORS

Demographic factors can affect rural and small community water supply issues through impacts on water quality, the need for additional water supply infrastructure, and the ability to pay for new or existing infrastructure. Nebraska’s population has increased by nearly a quarter since 1950, rising by an estimated 326,583 people between the 1950 census and July 1996 population estimates. However, that growth was not distributed evenly. The Omaha and Lincoln metropolitan areas grew by 375,121 people over that period, and so population in the state's rural areas actually declined somewhat. The University of Nebraska's Bureau of Business Research projects the state’s population to increase 13.6% between 1990 and 2010. Fifty-seven of the state’s 93 counties are expected to have increases in working age population.

The economic well-being of communities and their capacity to pay are significant factors in water infrastructure decisions. Supalla and Ahmad (1997) developed a financial capacity index based upon average household valuation and the percent of households in 10 different income classes. Their estimates of financial capacity for 440 Nebraska communities with populations of 5,000 or less ranged from $9 to $110 per household per month. That type of range indicates major variations in community capacity. Yet infrastructure construction decisions depend on factors other than financial capacity, such as financial obligations, expected population changes, income source types (fixed or variable), and other public works problems.

Social factors that must be taken into account in dealing with elevated levels of nitrate in drinking water include fear, inconvenience, and health risks.

CURRENT AND FUTURE SMALL COMMUNITY AND RURAL DOMESTIC WATER DEMAND

Future small community and rural domestic water demand will depend upon population change, water rates, climatic conditions, and conservation practices. U.S. Census Bureau figures indicate that, of 330 Nebraska communities of under 500 population in 1990, about 63% (207) had declined in population since 1970. The median community in this group had experienced a 7% population decrease. Of the 205 communities of more than 500 people, 52% (106) declined in population over the same period. Of 535 total Nebraska communities, 313 declined in population over the 20-year period. Declining population could affect ability to pay in some communities forced to make water infrastructure improvements.

Based on Bureau of Business Research projections, the state's population as a whole is expected to increase by 13.6% between 1990 and 2010. The Bureau's map of projected population change from 1990 to 2010 is presented in figure 11. This increase will not be evenly distributed. The metropolitan counties (those having the largest base population) are expected to have the fastest growth. The increases will be less for large trade-center counties and even slower for counties considered small trade counties. Rural counties' populations are expected to decrease by 6.7 percent.

While population is the most important factor to examine when determining small community and/or rural domestic water demand, other factors also affect per capita demand. These include changes in household size, changes in conservation measures, changes in industrial-commercial use, changes in system efficiency and changes in the cost of water to the consumer.

The number of households in Nebraska is growing at a faster rate than total population. Between 1980 and 1990, while Nebraska population grew 5.0%, the number of households grew about 10.4%. Small households tend to use more water per capita than larger households. Therefore, a continued trend toward smaller households could increase per capita water use rates to some degree. Any effort to project future water use in Nebraska's small communities and rural areas would need to consider not only population projections but also trends in household size.

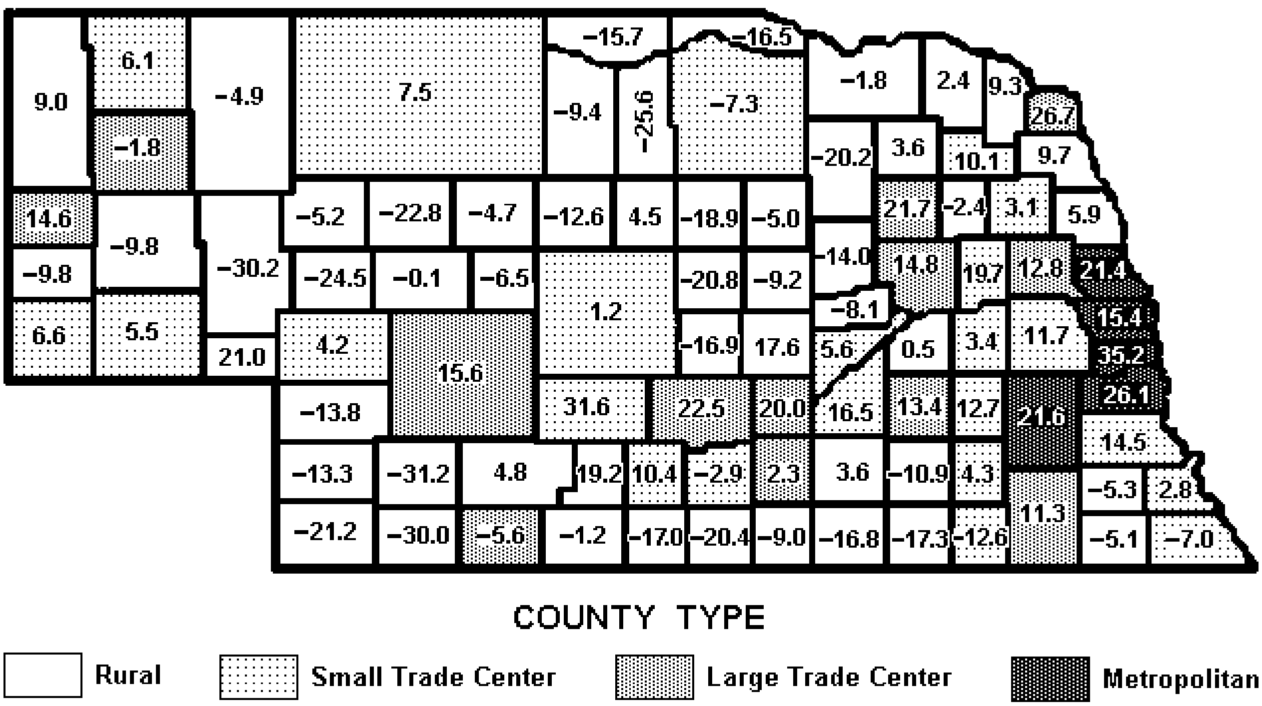
Increased awareness and adoption of conservation measures may also influence domestic water demand to some degree in future years and could provide significant savings to commercial enterprises. In an individual small community an industrial water user can play a significant role in total water use. Just as the opening or closing of such an enterprise can significantly alter a community's per capita use figures, so can the institution of conservation measures by the industrial user.

Changes in system efficiency may also play a role in per capita use. Some aging systems have significant leakage, which may be controlled when new mains are installed. Many of Nebraska's small communities do not meter individual water use. If metering began in some of those communities, it would probably lead to some decrease in demand.

Figure 11

Projected Population Growth by County, 1990 to 2010

[Increases or Decreases (–) in Percent]



FACTORS THAT MAY AFFECT SUPPLY

Land Use/Human Activities

Various land-use activities could affect rural and small community water supply in Nebraska, including:

- *General type of land use.*—Harvested cropland in 1992 comprised just under 1/3 of the state’s total land.

- *Changes in irrigated acreage.*—The amount of irrigated farm land in Nebraska rose 190% in 28 years. It constituted 4.1% of the state's total land area in 1964 and had expanded to 12.9% by 1992 (U.S. Census of Agriculture, 1964 and 1992).

- *Changes in cropping patterns.*—Corn accounted for almost 45% of harvested acreage in 1992, up from just over 37% in 1959. Soybean acreage grew from less than 1% of harvested acreage in 1959 to more than 14% in 1992 (U.S. Census of Agriculture, 1964 and 1992).

- *Fertilizer use.*—Between 1962 and 1994 the tonnage of commercial fertilizer sold in Nebraska rose 491% (NASS, various years). However, most of that increase was in the early portion of the time span. Tonnages sold have not increased greatly since the late 1970's.

- *Livestock numbers.*—Between 1950 and 1996 the inventory of hogs and pigs in Nebraska rose more than 64% and the number of cattle on farms rose more than 65%. However, cattle and calf inventories were almost the same in 1996 as they were in 1970, and hog and pig inventories in 1996 were lower than they were in 1980 and have declined further since 1996 (NASS, various years). However, from July 1997 through December 1998, DEQ received about 400 waste permit applications for livestock facilities of all sizes. Roughly half of these were for proposed new facilities. It remains to be seen whether the high permit application numbers will translate into increasing livestock numbers.

- *Waste disposal practices.*—The U.S. Census of Housing for 1990 reported that 117,460 housing units in the state were served by septic tanks or cesspools. Currently, DEQ uses a working estimate of 200,000 to 250,000 septic tanks in the state, with as many as 8,000 to 10,000 more being added each year (Steve Goans, DEQ, oral commun., 1998).

- *Groundwater use for irrigation.*—Cumulative registered irrigation well numbers in Nebraska rose from 4,068 in 1956, to 29,167 in 1966, to 84,501 in 1996. In 1995, irrigation accounted for more than 93% of Nebraska groundwater use. (Nebraska Department of Water Resources statistics, 1998.)

- *Domestic groundwater use.*— Registration of new domestic wells has been required since 1993. Annual statewide new domestic well registrations were 1,024 in 1994, 1,219 in 1995, 1,359 in 1996, and 1,447 in 1997. (Nebraska Department of Water Resources statistics, 1998.)

Standing alone, data showing increases in irrigation, human population, and some livestock populations, combined with the earlier increase in fertilizer use, would seem to indicate a corresponding increase in threats to the water supply. However, these data must be balanced against increased use of agricultural best-management practices, better waste-management practices, and better well-construction techniques. Also, irrigation water management, fertilizer use, and application timing are now addressed in the groundwater management plans of most of Nebraska's natural resources districts. Concerns about water quality and techniques for improving it are covered through a wide array of educational programs. In the 1990s, Nebraska has updated its solid-waste management policies and substantially reduced the number of landfills in the state.

Environmental Setting

Among the environmental setting factors most relevant to rural/small community water supplies are occurrence of groundwater, depth to the water table, and geologic factors. Other factors include topography, climate, soils, vulnerability to contamination, natural vegetation, and fish and wildlife.

- *Topography.*—Land slopes and elevations can constrain the degree to which land is utilized for irrigation or growing crops. Sloping land also is less likely than flat land to contribute to groundwater pollution; the slopes have higher rates of runoff and erosion, and both of these processes carry away contaminants that infiltrate the soil. Figure 12 is a map of Nebraska topographic features.

- *Climate.*—Precipitation, temperature, humidity, cloud cover, and winds can all affect the rural and small community water demand, which crops are grown in an area, and the potential for leaching or runoff of nutrients and pesticides.

- *Soils.*—Soil composition and texture can influence small community and rural water supplies by affecting the infiltration rate of contaminants from the surface. Permeability is the quality that enables water to move downward through the soil profile. Figure 13 is a map of generalized permeability conditions throughout the state.

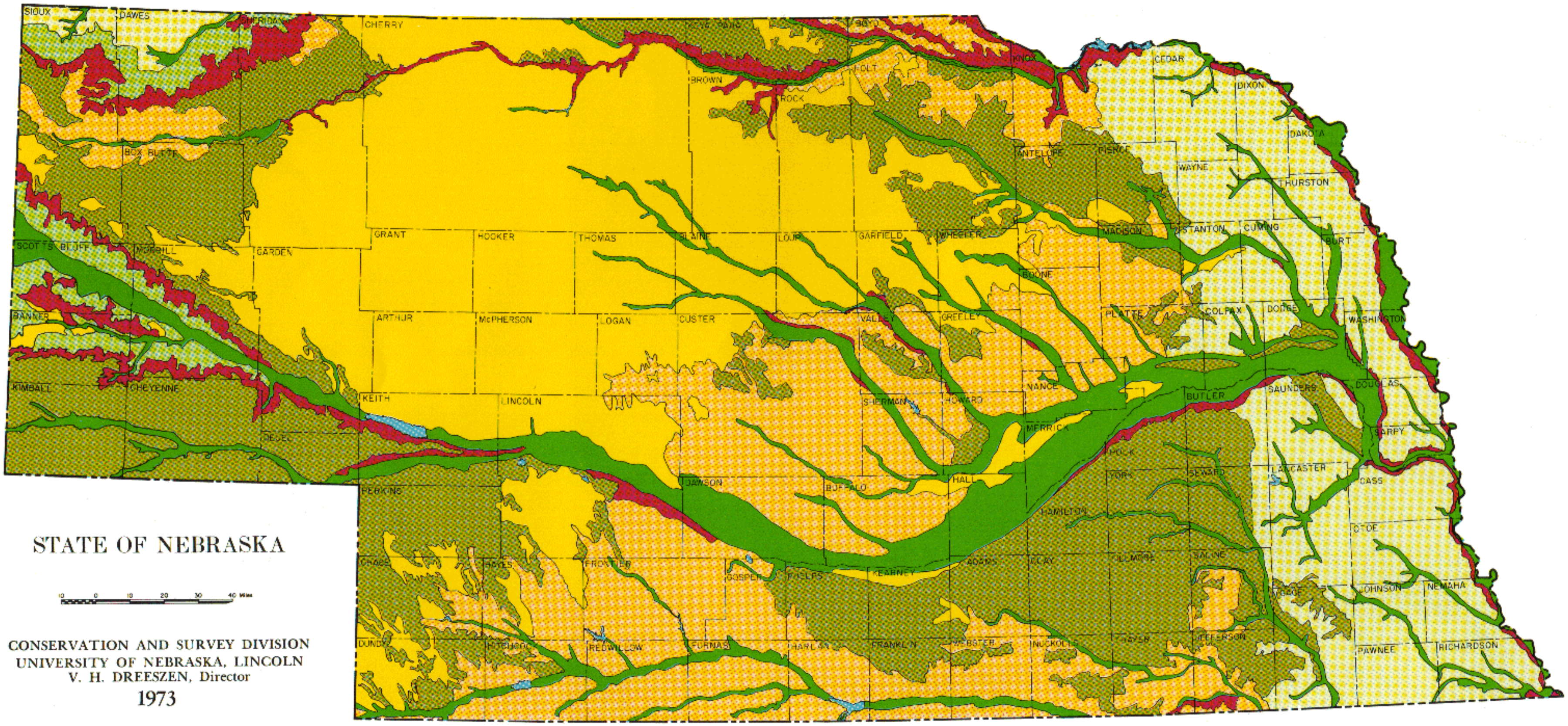
- *Vulnerability to contamination.*—Vulnerability results from a combination of several factors. Figure 14 is a generalized map of groundwater vulnerability to contamination based on the DRASTIC method. DRASTIC is an acronym for the factors used to estimate vulnerability: depth to the water table, recharge (amount of water that percolates down into the aquifer), aquifer media, soil media, topography (slope), impact of the vadose zone (time required for water to percolate through the unsaturated zone between the surface and the water table), and conductivity (hydraulic conductivity of the soil).

Vulnerabilities tend to be higher in river valleys, the Sandhills and Sandhills fringe areas, portions of the Panhandle, and the Upper Republican, Upper Elkhorn, Upper Big Blue, and Upper Little Blue Basins. Ideally the DRASTIC map should be compared with a land-use map (figure 15) and an irrigation wells map (figure 16). Application of potential contaminants to the soil surface is more likely in crop areas, irrigated areas, and urban areas than on range land. DRASTIC is useful in a small-scale state-level map but less reliable at larger scales. Generally, it is not good for cells smaller than 200 acres.

LEGAL/INSTITUTIONAL FACTORS

The array of legal and institutional factors affecting small community water supplies is so large that even providing a list of relevant laws and regulations can be confusing to the casual reader. This section of this report examines these factors in several categories: (1) the regulatory framework (including regulations pertaining to wells, water systems, and source water protection), (2) technical assistance programs and education, and (3) funding sources. Those categories include state, local, and Federal government responsibilities. Private assistance is also

Figure 12 — Topographic Regions Map



EXPLANATION

Valleys—flat-lying land along the major streams. The materials of the valleys are stream-deposited silt, clay, sand, and gravel.

Large Reservoirs—constructed for purposes such as water storage for irrigation, generation of electricity, flood control, or recreation.

Dissected Plains—hilly land with moderate to steep slopes, sharp ridge crests, and remnants of the old, nearly level plain. The Dissected Plains are old plains eroded by water and wind.

Rolling Hills—hilly land with moderate to steep slopes and rounded ridge crests. In eastern Nebraska, the Rolling Hills are mostly glacial till that has been eroded and mantled by loess, while in northwestern Nebraska the hills were produced by the erosion of clay and clay-shale beds.

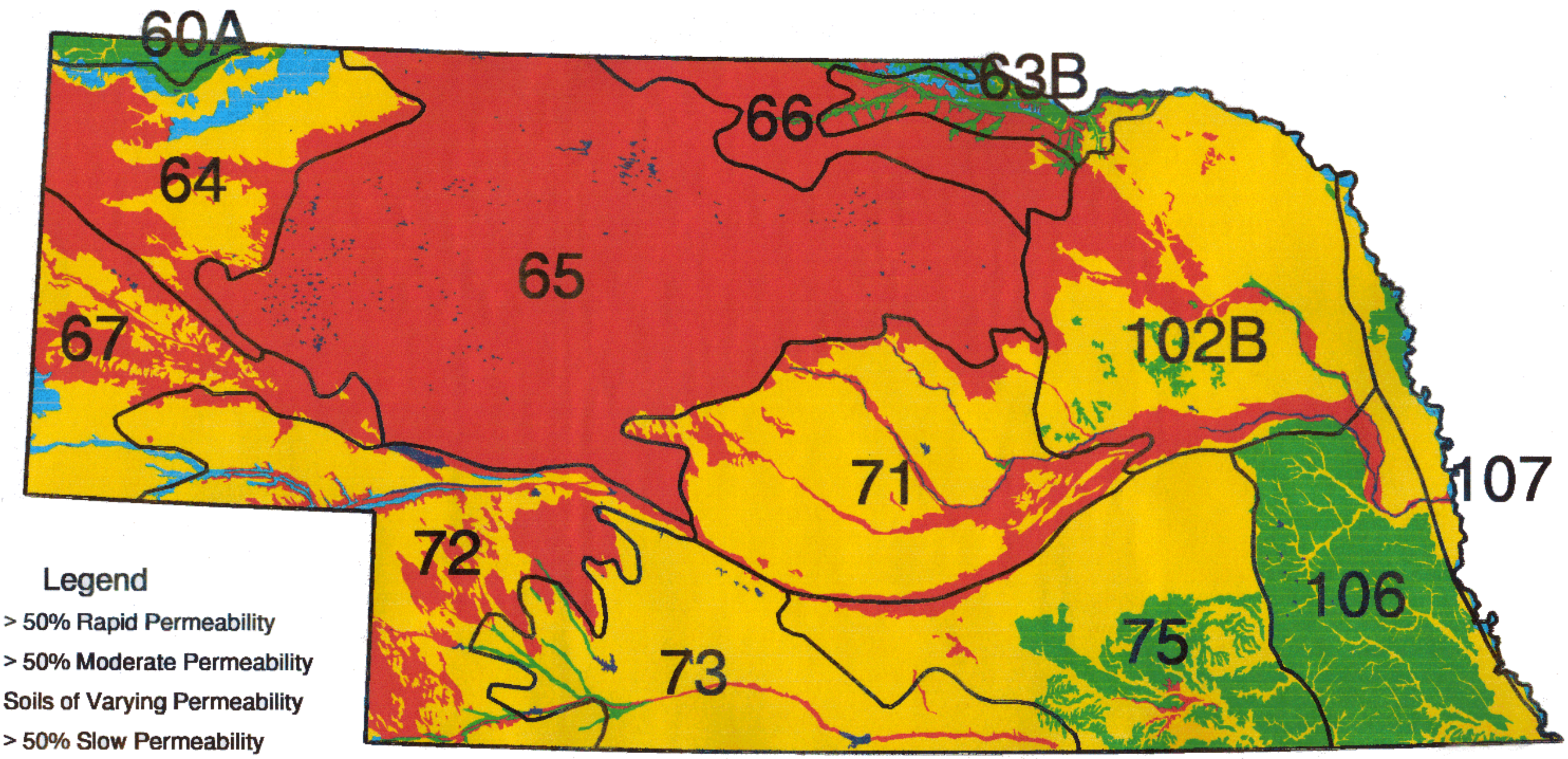
Valley-Side Slopes—moderately sloping land which occurs between the escarpments and the major stream valleys in western Nebraska. These areas are mostly siltstone bedrock covered by a few feet to a few tens of feet of sand, gravel, or silt.

Plains—flat-lying land which lies above the valley. The materials of the plains are sandstone or stream-deposited silt, clay, sand, and gravel overlain by wind-deposited silt (loess).

Sand Hills—hilly land composed of low to high dunes of sand stabilized by a grass cover. The sand dunes mantle stream-deposited silt, sand and gravel, and sandstone.

Bluffs and Escarpments—rugged land with very steep and irregular slopes. Bedrock materials, such as sandstone, shale, and limestone, are often exposed in these areas.

Figure 13
Major Land Resource Area and Soil Permeability Map



Legend

- > 50% Rapid Permeability
- > 50% Moderate Permeability
- Soils of Varying Permeability
- > 50% Slow Permeability
- Water

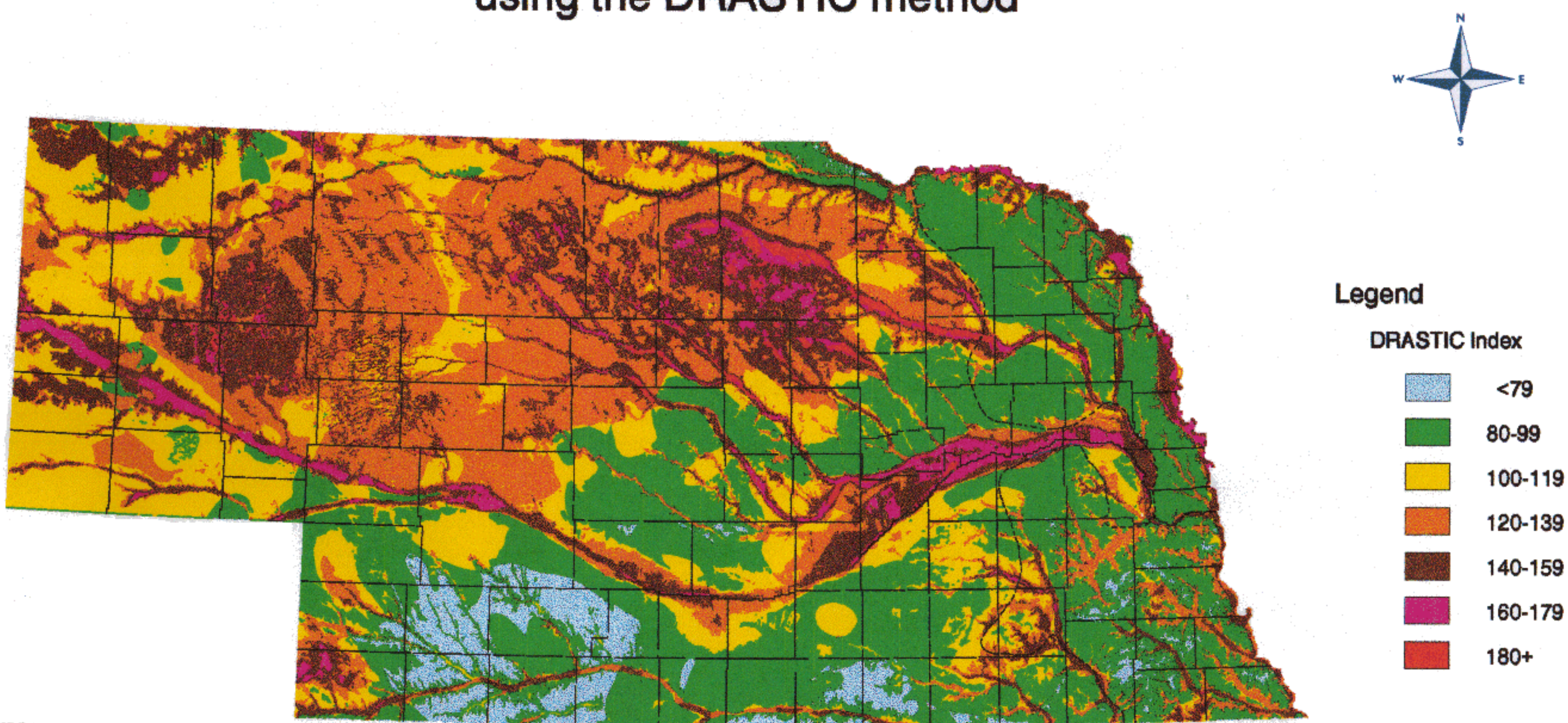
60A	Pierre Shale Plains and Badlands
63B	Southern Rolling Pierre Shale Plains
64	Mixed Sandy and Silty Tableland
65	Nebraska Sand Hills
66	Dakota-Nebraska Eroded Tableland
67	Central High Plains
71	Central Nebraska Loess Hills
72	Central High Tableland
73	Rolling Plains and Breaks
75	Central Loess Plains
102B	Loess Uplands and Till Plains
106	Nebraska and Kansas Loess-Drift Hills
107	Iowa and Missouri Deep Loess Hills

Produced By - Natural Resources Commission
STATSGO Soils Data - NRCS
Interpretation - Natural Resources Commission
GIS Process - ARC/INFO
Processed - September, 1997

NEBRASKA NATURAL RESOURCES COMMISSION

DATA BANK

Figure 14
Potential Groundwater Vulnerability to Contamination using the DRASTIC method



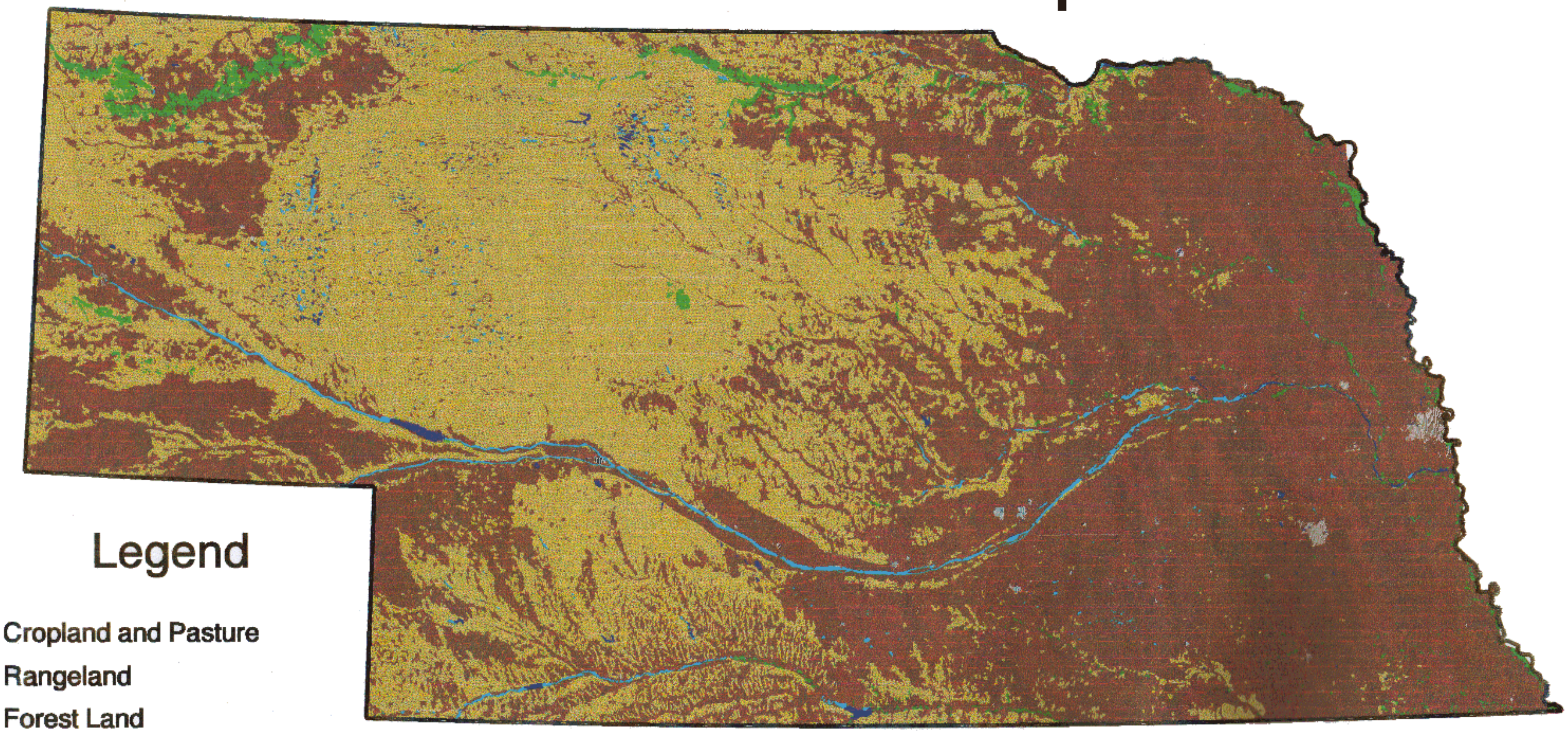
Information Source:

Produced by *- Nebraska Natural Resources Commission*
Model *- U.S. Environmental Protection Agency, and National Water Well Association*
Data Source *- Department of Environmental Quality, Center for Advanced Land Management Information Technoogies. Conservation and Survey Division, UNL*
DRASTIC Parm *Depth to Groundwater, recharge, Acquifer media, Soil Media, Topography (slope), Influence of Vedose Zone, and Hydraulic Conductivity*
GIS Process *- ARC/INFO*
Processed *- October 1996*

NOTE: *This map is for planning purposes only and is not intended to be used for site-specific applications.*

DRASTIC indices east of the dashed line represent only the vulnerabilities of the upper most ground-water level.

Figure 15
Nebraska Landuse Map



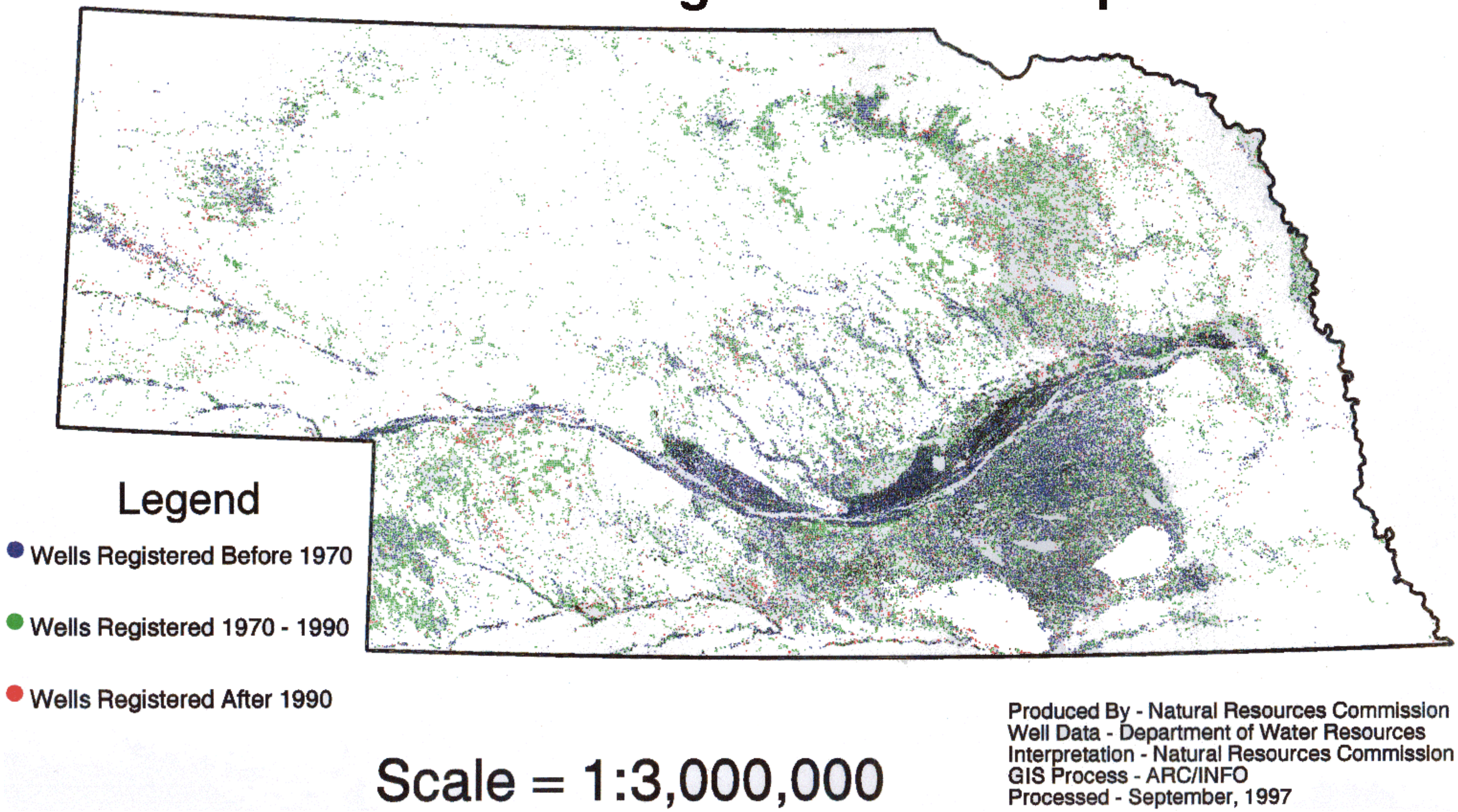
Legend

- Cropland and Pasture
- Rangeland
- Forest Land
- Urban or Built-up Land
- Water
- Wetlands

Scale = 1:3,000,000

Produced By - Natural Resources Commission
Landuse Data - U.S. Geological Survey
Landuse/Landcover
Interpretation - Natural Resources Commission
GIS Process - ARC/INFO
Processed - September. 1997

Figure 16
Nebraska Irrigation Wells Map



possible in categories 2 and 3. In most instances, Federal laws and regulations are in practice implemented through parallel state regulations.

In general, state-level regulation of public water suppliers in Nebraska is provided through HHSS's Department of Regulation and Licensure, though some related statutes are administered by the Nebraska Department of Water Resources. Private wells are subject to regulations governing water well construction (since 1988) but are not subject to state or Federal water quality testing or water quality standards. State-level source water protection regulation is generally provided through DEQ, although pesticide regulation is provided through the Nebraska Department of Agriculture. On the local level, the state's 23 natural resources districts have the authority to regulate non-point sources of groundwater contamination. Most of the above agencies and a variety of other agencies and private entities generally provide technical assistance and education programs relevant to various aspects of public water supplies and source water protection.

In addition to community funding sources, the primary government sources of funding for public wells and water systems include (1) The Community Development Block Grant Program of the U.S. Department of Housing and Urban Development (administered in Nebraska by the Nebraska Department of Economic Development), (2) water and wastewater grants and loans from the U.S. Department of Agriculture Rural Utilities Service, and (3) the State Revolving Loan Fund portion of the Federal and state safe drinking water acts.

Regulatory Framework

Most rules and regulations to administer state laws concerning water wells, water systems, and groundwater protection are codified in legal documents called "titles." Most of these titles are administered by DEQ, the Department of Regulation and Licensure of HHSS, the State Fire Marshall's Office, and the Oil and Gas Conservation Commission. Additional legal authority is provided through statutes administered by the Department of Water Resources (DWR) and the Nebraska Department of Agriculture, and through statutes enabling action by local units of government.

The following paragraphs do not focus on Federal laws or regulation since, in practice, most of the relevant portions of those laws and regulations are implemented by parallel state regulations.

Well and Water System Regulation

Titles or statutes pertaining to state-level regulation of water wells or water systems address the following topics:

1. Public water-well permits, drinking water standards, monitoring, well siting, design, construction, operator certification, administrative orders, and exemptions (The Nebraska

Safe Drinking Water Act—NRS 71–5301 to 71–5313. Also title 179, chapter 2, HHSS). (The act also establishes an Advisory Council on Public Water Supply).

2. Water-well construction, pump installation, and water-well abandonment standards (title 178, chapter 12, HHSS).

3. Licensure of water well and pump installation contractors (including education requirements) and certification of water well drilling, pump installation and water well monitoring supervisors (title 178, chapter 10, HHSS).

4. Registration of water wells and notice of abandonment (NRS 46–602, and title 456, DWR).

5. Well spacing (Nebraska Revised Statutes 46–609, 46–651 to 46–654, and title 456, DWR).

6. Municipal and rural domestic groundwater transfer permits (NRS 46–638 to 46-650 and Title 456, DWR).

7. Transfers of water for industrial purposes (NRS 46–675 to 46–690, and Title 456, DWR).

8. Application for surface water rights (NRS 46–233 through 46–242).

Nitrate Monitoring and Administrative Orders For Communities

The Director of Regulation and Licensure for HHSS is charged with issuing permits to operate public water systems and with setting drinking water and monitoring standards for those systems. That authority is provided by the Nebraska Safe Drinking Water Act (NRS 71–5301 to 71–5313). The act also allows the director to issue an administrative order specifying corrective action when any person or entity has violated the act, a regulation promulgated under the act, or an exemption. The director may issue variances or exemptions to the act so long as they are not less stringent than those allowed under the Federal Safe Drinking Water Act.

HHSS has promulgated regulations governing public water systems (title 179, chapter 2) and standards for monitoring nitrate. According to those regulations, groundwater entry points for community and nontransient systems are to be monitored annually unless a sample shows nitrate equal to or greater than 5.0 milligrams per liter. Samples must then be taken quarterly until after four consecutive quarters are below 8.0 milligrams per liter. Water that is above the MCL at the entry point but is treated to meet standards is required to be monitored quarterly.

Private Well Regulation

Private wells are not regulated under the Federal Safe Drinking Water Act but are subject to state well construction regulations. State well construction regulations apply to wells installed or reconstructed since 1988. Recommended standards were available in 1974. Private wells are not subject to state or Federal water quality standards or testing requirements. Some commercial mortgage lenders require that private wells be tested as a condition of loan approval, and some Federal agencies (e.g., the Department of Housing and Urban Development and the Department of Veterans Affairs) require testing as a prerequisite for providing mortgage insurance. Inspection of new or existing private wells is not required.

Regulation for Source Water Protection

A number of laws and regulations can help protect sources of drinking water, including almost the full spectrum of the state's land and water pollution prevention laws. Titles or statutes pertaining to state-level protection of groundwater quality or drinking water sources include:

1. Groundwater quality standards and use classification (title 118, DEQ).
2. Effluent guidelines and standards (title 121, DEQ).
3. Underground injection and mineral production wells (title 122, DEQ).
4. Design, operation and maintenance of wastewater treatment works (title 123, DEQ), septic tanks, and individual waste treatment lagoons (title 124).
5. Waste management (title 126, DEQ).
6. Solid waste management (title 128, DEQ).
7. Livestock waste control (title 130, DEQ).
8. Integrated solid waste management (title 132, DEQ).
9. Underground storage tanks (title 159, DEQ).
10. Low level radioactive waste disposal (title 194, DEQ).
11. Chemigation (title 195, DEQ).
12. Special protection areas/non-point-source groundwater contamination (title 196).
13. Fertilizer and pesticide storage and handling (title 198, DEQ).
14. The Nebraska Pesticide Act—pesticide registration and licensing of dealers and applicators (NRS 2-2622 to 2-2655, Nebraska Department of Agriculture).
15. Oil and gas drilling (title 267, Oil and Gas Conservation Commission).

Laws Enabling Local Regulation

Other statutes support local action—by communities, counties, and natural resources districts—to protect groundwater. These laws include:

1. Local zoning, subdivision, building-code, and other authorities, which can be used to protect public health. These are found in a number of sections throughout the statutes. In addition, conservation easement or land purchase and leaseback can be used to protect community water sources. Wellhead protection programs can help protect beyond the 1,000-foot well setback required by HHSS regulations.

2. Extraterritorial jurisdiction beyond corporate limits of cities and villages—1 mile for villages and cities of the second class (NRS 17–1001), 2 miles for cities of the first class (NRS 16–901), 3 miles for primary and metro-class cities (NRS 15–201.01 and 14–418).

3. Villages and cities of the second class may have a 15-mile jurisdiction to protect the source of their water (untested law from the 1800's) (NRS 17–536).

4. The Groundwater Management and Protection Act (NRS 46–656.01 to 46–656.67) The act enables natural resources districts to regulate water users in groundwater management areas through allocation of withdrawal, rotation of use, well spacing, mandatory well metering, reduction of irrigated acres, mandatory chemical analysis of deep soils, or water quality monitoring and reporting requirements. Districts also perform a wide variety of monitoring and educational activities in groundwater management areas. A map showing groundwater management areas as of April 1999 is included as figure 17. At that time, groundwater management areas covered more than 55% of the state's area.

5. The Wellhead Protection Area Act authorizes the controlling entity of any public water supply system to adopt boundaries and controls for a wellhead protection area.

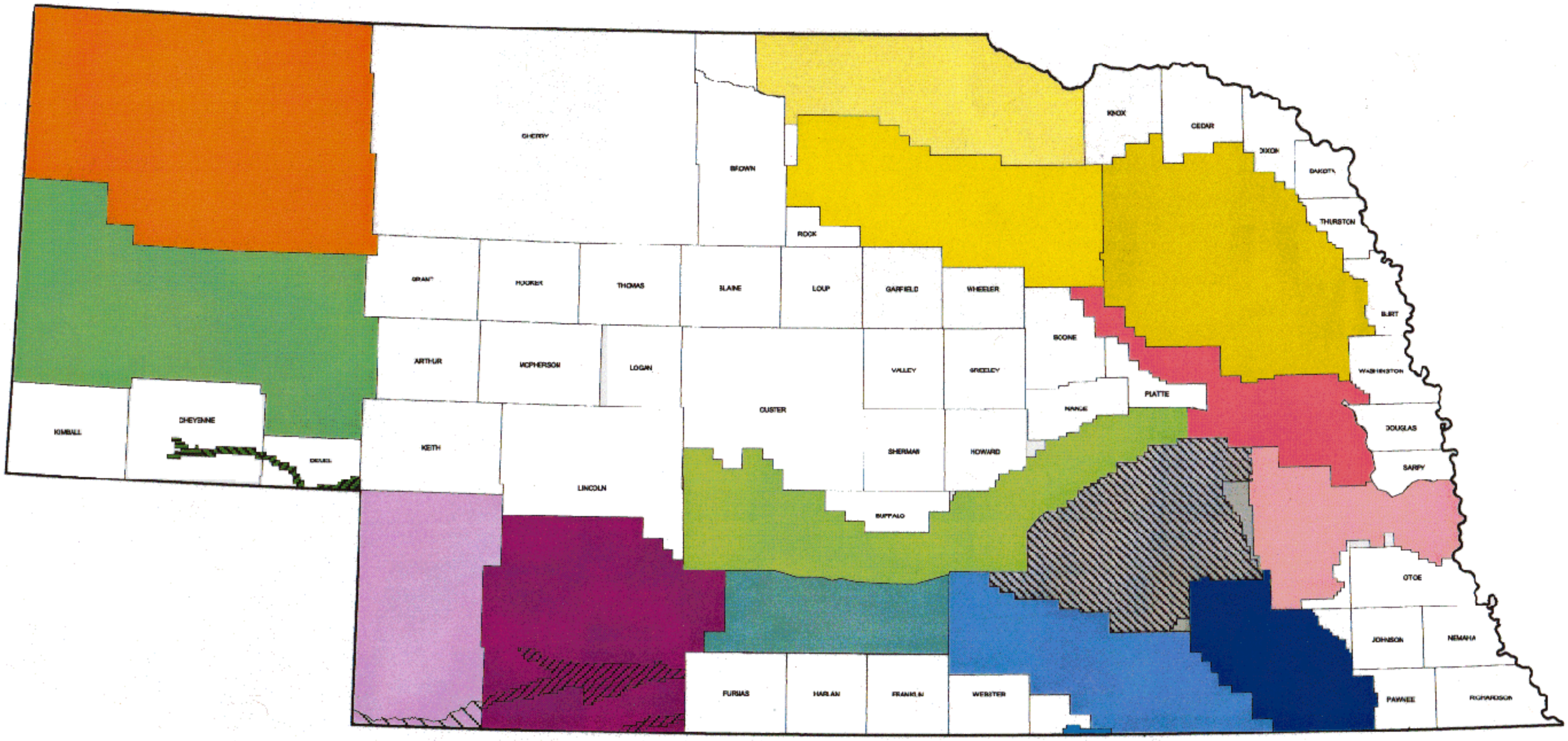
While the intent of these laws is generally to protect human health; citizens of individual communities may not agree that the legal/institutional structure works to that end in each of their cases. Potential discussion points, issues or problems related to the regulatory framework for rural domestic and small community water supplies include the following:

1. Frequent changes in Federal drinking water standards can make it difficult for a community to plan water supply improvements and can result in considerable waste of money as communities attempt to meet changing requirements through piecemeal action.

2. Many communities may not take advantage of the enabling legislation to protect water sources.

3. Even communities that take the actions allowed by statute may find them inadequate to prevent contamination of drinking water sources.

Figure 17 – Ground Water Management Areas



- Central Platte (6/1/88)Qq
- Deuel County (2/13/95)q
- East Lodgepole Valley (9/10/98)q
- Little Blue (10/28/96)Qq
- Lower Big Blue (2/3/97)q
- Lower Elkhorn (1/1/97)q
- Lower Niobrara (7/1/96)q
- Lower Platte North (1/1/97))q
- Lower Platte South (8/13/96)Qq
- Middle Republican (7/1/98)q
- North Platte (7/10/96)Qq
- Red Willow-Hitchcock (SPA 10/17/91)q *
- Sidney (12/10/90)q
- Superior-Hardy (SPA 2/13/90)q *
- Tri-Basin (8/17/89)q
- Upper Big Blue (12/9/77)Q
- Upper Big Blue (SPA 9/23/93)q *
- Upper Elkhorn (6/30/97)q
- Upper Niobrara-White (7/1/98)q
- Upper Republican (8/1/77)Q
- Upper Republican (10/3/97)q

* Water well construction permits required for former Special Protection Areas after July 19, 1996
Q = quantity management area
q = quality management area
Qq = quantity and quality management area

Department of Water Resources
revised 11/23/98 drv

4. *Groundwater protection responsibilities are split between communities, NRDs, and state and Federal entities.*

5. *No monitoring is required for private domestic wells, nor are such existing wells required to meet water quality standards. This may save needless expense for some well owners but may also allow contamination to go undetected.*

Technical Assistance Programs and Education

Programs at the local, state, and Federal levels provide technical assistance and education related to water source protection and public water wells and water systems. Addresses and phone numbers for some of the organizations that provide such programs are included as attachment B. Those programs include:

1. Nebraska's Source Water Assessment Program (administered by DEQ). This program is intended to (1) identify areas that supply public drinking water, (2) inventory contaminants and assess water system susceptibility to contamination, and (3) inform the public of its results.

2. The Nebraska Wellhead Protection Program (administered by DEQ)

3. The Nebraska Mandates Management Initiative (administered by DEQ)

4. University of Nebraska–Lincoln (UNL), Conservation and Survey Division, Public Well Location Assistance

5. Wastewater operator certification (NDEQ) and drinking water operator certification (HHSS) education programs

6. Natural Resources Districts' groundwater management and education programs

7. University of Nebraska Cooperative Extension Programs (The Farm*A*Syst programs are especially helpful in addressing farmstead and acreage homesite water quality problems.)

8. The Natural Resources Conservation Service's conservation programs (These provide conservation assistance to agricultural landowners and can have significant water quality impacts to lands near wells.)

9. Private, statewide educational and assistance efforts through such organizations as the Nebraska Rural Water Association, the Midwest Assistance Program, the Nebraska Well Drillers Association, the Nebraska League of Municipalities, and the Groundwater Guardian Program of the Nebraska-based Groundwater Foundation. For instance the Nebraska Well Drillers Association in cooperation with the UNL Conservation and Survey Division has

published a brochure entitled “So You Need a Water Well?—A Consumer's Guide to Homeowners' Drinking Water” (also available on the Internet at http://nesen.unl.edu/csd/illustrations/mp43/mp43.html).

10. DEQ’s 319 non-point-source management program (funded under section 319 of the Clean Water Act) is a comprehensive and dynamic program providing funding, reporting, education, and other assistance.

11. Consumer Confidence Report requirements for local water suppliers. These new requirements will provide added information to water system customers.

12. Some NRDs, the Department of Environmental Quality, and the Nebraska Rural Water Association have cooperated in circuit-rider programs to assist small communities.

13. The Cooperative Extension Service and the NRDs have ongoing programs to address water quality, including testing. Farm Service Agency offices are another source of information.

14. The University of Nebraska Water Center is developing a data clearinghouse which is to include nitrate data.

Sources of free or low-cost technical assistance and education at the national level include the Environmental Protection Agency, the EPA Safe Drinking Water Hotline, the American Water Works Association, the Rural Community Assistance Program, the Environmental Quality Instructional Resource Center (housed at Ohio State University), and the National Drinking Water Clearinghouse.

As of late 1997, the Nebraska Rural Water Association provided technical assistance on wellhead protection programs, with a goal of assisting at least 13 communities per year.

The Midwest Assistance Program helps communities in assessing infrastructure needs and in writing Community Development Block Grant applications and other grant fund applications.

The Nebraska Mandates Management Initiative is an especially promising effort in which state and local agencies provide extensive technical assistance directly to communities that choose to participate. In April 1995, a task group working under the initiative issued a report listing significant water-quality-related technical assistance programs. Between May 1995 and October 1997, 69 communities participated fully in the initiative. Nitrate in drinking water supplies was identified as an important issue in 39 of those communities. The mandates management process was also used to develop a common water/wastewater funding application (attachment D), which can be used to apply for both Federal and state infrastructure.

The Nebraska Wellhead Protection Program is intended to prevent groundwater pollution from entering public water supply wells and making them unusable. This program has provided significant technical assistance to communities through the delineation of maps showing potential contaminant time of travel for over 200 of those communities. It also provides a manual and assistance for communities wishing to conduct contaminant source inventories and considerable information on wellhead protection.

Wellhead protection can be used as an option when a community is under administrative order for violation of nitrate standards and nitrate levels are below 15 mg/L. In such instances bottled water must be provided to infants and pregnant women. A large number of specific wellhead protection activities are detailed in DEQ literature. Communities with wellhead protection programs have a number of options, including conservation easements, land purchase and leaseback, local zoning/land-use controls, and, in some cases, seeking assistance from local natural resources districts (NRDs). NRDs sometimes have provisions in their groundwater management plans to assist with wellhead protection.

The Source Water Assessment Program is part of a 50-state effort inaugurated by the 1996 amendments to the Safe Drinking Water Act. In January 1999, DEQ submitted a source water assessment plan to the U.S. Environmental Protection Agency. Under this plan, DEQ will study all public water systems in the state, inventory identified contaminants, attempt to determine the systems' susceptibility to contaminants, and inform the public of its findings. It will have until mid-2003 to complete the assessment.

In addition to the licensure, certification, and education requirements for water well and pump installation contractors, HHSS also offers a technical assistance program and will inspect the condition of a well and look for potential sources of contamination. However, inspection of new or existing private wells is not required.

Potential issues, problems, and options associated with existing wellhead protection programs and educational efforts include the following:

1. *In the past, communities sometimes adopted treatment or other water supply options without fully consulting all possible sources of assistance. Communities need to be fully aware of technical assistance options and should adequately explore all alternative means of addressing water supply needs.*

2. *Currently, no statewide program guarantees that areas upgradient of community wells are monitored.*

3. *Communities are not taking full advantage of the Nebraska Wellhead Protection Program. As of late 1997, only 15 or 16 communities (out of 628 statewide) were known to have conducted contaminant source inventories. It is also important for communities to take full advantage of DEQ's Source Water Assessment Program.*

4. *Private well owners need to be better informed about testing needs and potential risks. A 1994 survey of 5,520 private well owners by the Centers for Disease Control (CDC, 1998) over a nine-state region found that 44 percent of respondents*

indicated their well had been tested for contamination, 44 percent said their well had never been tested for contamination and 11 percent did not know. Among those who said their wells had been tested, 39 percent indicated that the testing took place prior to 1990 (GAO, 1997, p. 20). Although private well owners in Nebraska may be better informed about potential drinking water concerns than consumers in some other states, additional public information efforts may be useful in some situations.

According to the GAO (1997), the lack of information by private well owners

> . . . does not imply that private well users are all at risk or that they should begin to test their water for all of the contaminants regulated by community water systems. That would be unnecessarily expensive. What it does suggest is that when there is information already available from community systems that could alert private well users to possible local contamination problems, these users could benefit from that information. For example, community water systems could provide a copy of their annual water quality report to state and/or local public health agencies, which could then alert private well users to localized contamination problems and advise them to consider having their well tested for specific pollutants, if appropriate. The agencies could publicize the availability of the annual report through the local media, making sure that the notice alerts private well users to the report's potential relevance to their water supply. With the information from the annual report, private well users can make informed choices about testing or maintenance. Without the information, they may not be aware of potentially harmful contamination.

Funding Sources

Funding for public wells, water systems, and water source protection is available from a variety of sources. Addresses and phone numbers for some of the organizations that provide such funding are included as attachment C. Here is a partial listing of funding sources:

For public wells and water systems:

1. The Drinking Water State Revolving Fund portion of the Federal and state Safe Drinking Water Acts. The fund program provides loans to eligible public water supply systems for the construction of waterworks and land acquisition for source water protection. Funds can be used to plan, design, and construct drinking water facilities. A portion of loans made under this program may be forgiven for communities having median household incomes less than the state average. The fund is administered jointly by DEQ, HHSS, and the Nebraska Investment Finance Authority.

2. Water and wastewater grants and loans from the U.S. Department of Agriculture's Rural Utilities Service.

3. Community Development Block Grants from the U.S. Department of Housing and Urban Development. In order to receive a grant from this source a community's average water system charges must be at least 1% of median household income. (These grants are administered through the Nebraska Department of Economic Development).

   (Note: The Nebraska Mandates Management Initiative has developed a consolidated grant application form (attachment D), which can be used for all three of the above programs).

4. Community Revenue Bonding Authority

5. Community Taxing Authority

6. General Obligation Bond Authority

7. Community User Fee Authority

8. Department of Interior Funds for Indian Reservation Water Systems

9. Federal Emergency Management Agency Funds (for systems damaged by flooding)

10. Bureau of Reclamation assistance in limited circumstances

11. Water 2000 Safe Drinking Water Initiative Funds

For water-source protection:

1. Environmental Protection Agency "319 Program" non-point-source pollution grants (funded under section 319 of the Clean Water Act)

2. Federal Safe Drinking Water Act funds passed on to state and state revolving fund (a state may allocate up to 15% for source water protection)

3. Agricultural land treatment funds (including the Nebraska Soil and Water Conservation Fund, Natural Resources Conservation Service Funds, and Natural Resources District cost-share programs)

4. The Nebraska Environmental Trust

5. The Nebraska Environmental Enhancement Fund (scheduled to lapse in December 2000 due to sunset provisions)

6. The Nebraska state revolving loan fund for wastewater (Among other provisions, this will allow low-interest loans for acquisition of easements on land in a wellhead protection program)

7. The Nebraska Water Well Decommissioning Fund

8. The U.S. Department of Agriculture's Conservation Reserve Program (provides 10 to 20 percent in extra funds for conservation easements in wellhead protection programs). Land within a 2,000-foot radius of a municipal well has a competitive advantage in the land selection process.

Potential issues or problems associated with funding programs for public and private water wells and systems and for water source protection include the following:

1. *Although funding programs for water systems have been relatively stable, some communities may still postpone needed action until either (a) better grant or loan conditions are available, or (b) the community's circumstances meet the need requirements. This can delay needed action.*

2. *The number of funding programs and their various deadlines can make application processes and coordination difficult. The Nebraska Mandates Management Initiative has a process to address this problem, but it is relatively new and not every community uses it. A copy of the common application developed through the process is included as attachment D.*

3. *A special program might be useful in helping phase out large-diameter dug private domestic wells, which account for many of the water quality problems of eastern Nebraska domestic wells. However, addressing other substandard wells is also important.*

4. *Point-of-use or point-of-entry treatment systems could be further examined for private wells with nitrate or other water quality problems.*

Local Government Management Options

Local governments can derive income to address water system concerns from a variety of sources. These include:

Income Only	Repayable
Customer Charges	Loans
Property Tax	General Obligation Bonds
Sales Tax	Revenue Bonds
Revenue Sharing	
Grants	

Local governments also have various options for the management of water utilities. These include the following:

1. Agreements with outside providers.
2. System independence, including the degree to which the water system subsidizes or is subsidized by other city operations.
3. Interlocal cooperation agreements, including interlocal personnel agreements.
4. Using a mix of funding to finance continuing operations.

The factors that influence a local government's decisions in this area include the level of need, local income, other local spending priorities, tax lids, Federal and state mandates, and grant and loan availability.

The perception of the need for an upgrade can be a major influence. The cost of an upgrade can be quite high, and postponing such expenditures can make a major financial difference to a community. Therefore, it is natural for communities to postpone such expenditures so long as community health is not compromised and long-term costs aren't increased. Major capital expenditures on water systems can also have the disadvantage of providing immediate increases in rates and long-term indebtedness while often providing no visible change in the product being delivered. This means evidence of the level of need is very important.

The availability of revenue—in terms of local income, other local spending priorities, tax lids, and local tax levels—is also a major factor in local water system decisions. If the cost of a system improvement would preclude fulfilling other needs or would stretch the limits of a community's ability to pay, it can place hardship on the community. These factors have helped create demands for grant programs.

Federal and state mandates define the level of service a system must provide. Minimum training and testing requirements affect ongoing costs, and maximum contaminant levels set a minimum standard for water quality. However, the changeability of Federal and state mandates can add to a community's quandary in upgrading water system components. This can be especially true for newly established MCLs. A community can invest in one type of treatment or system option only to find the rules have changed and that a different option is now required to meet the new standards. A community may also wish to delay action until it knows what new standards are likely to be.

Another major factor in local government decision making is the availability of grants and loans. For instance, of the 59 community water systems that, since 1981, have upgraded or are currently upgrading their systems in response to nitrate problems, at least 42 received assistance from the Community Development Block Grant Program. Because grant and loan programs have a major effect on community costs, and their funding levels can change through time, they may also affect the timing of community decisions.

A major potential weapon in a community's pollution prevention arsenal is the wellhead protection program. The use of contaminant source inventories, land purchase and leaseback, conservation easements, or land-use control can help prevent future threats to a community's water sources. The financing of these prevention options may result in immediate costs but perhaps greater long-term benefits.

NITRATE DATA ANALYSIS

NATURE OF COMMUNITY WATER SYSTEM NITRATE DATA

Historical community water system nitrate data is maintained by HHSS in a number of forms: (1) water quality data collections printed by the Nebraska Department of Health in 1967, 1969, 1971, 1973, 1975, 1982, and 1984; (2) hard-copy tabulations of sampling data in separate files for each community water system; (3) some unpublished historical water quality data from 1952–53 and 1947–48 in HHSS files; and (4) a computerized electronic file containing more than 14,000 sampling records for small systems, collected between 1970 and 1999.

Through time, Nebraska communities have completed required sampling, and HHSS has maintained records of samples. However, those records can be in one or more of the above forms. HHSS has copied many of its records to electronic format, but for a number of past years, these electronic files are incomplete.

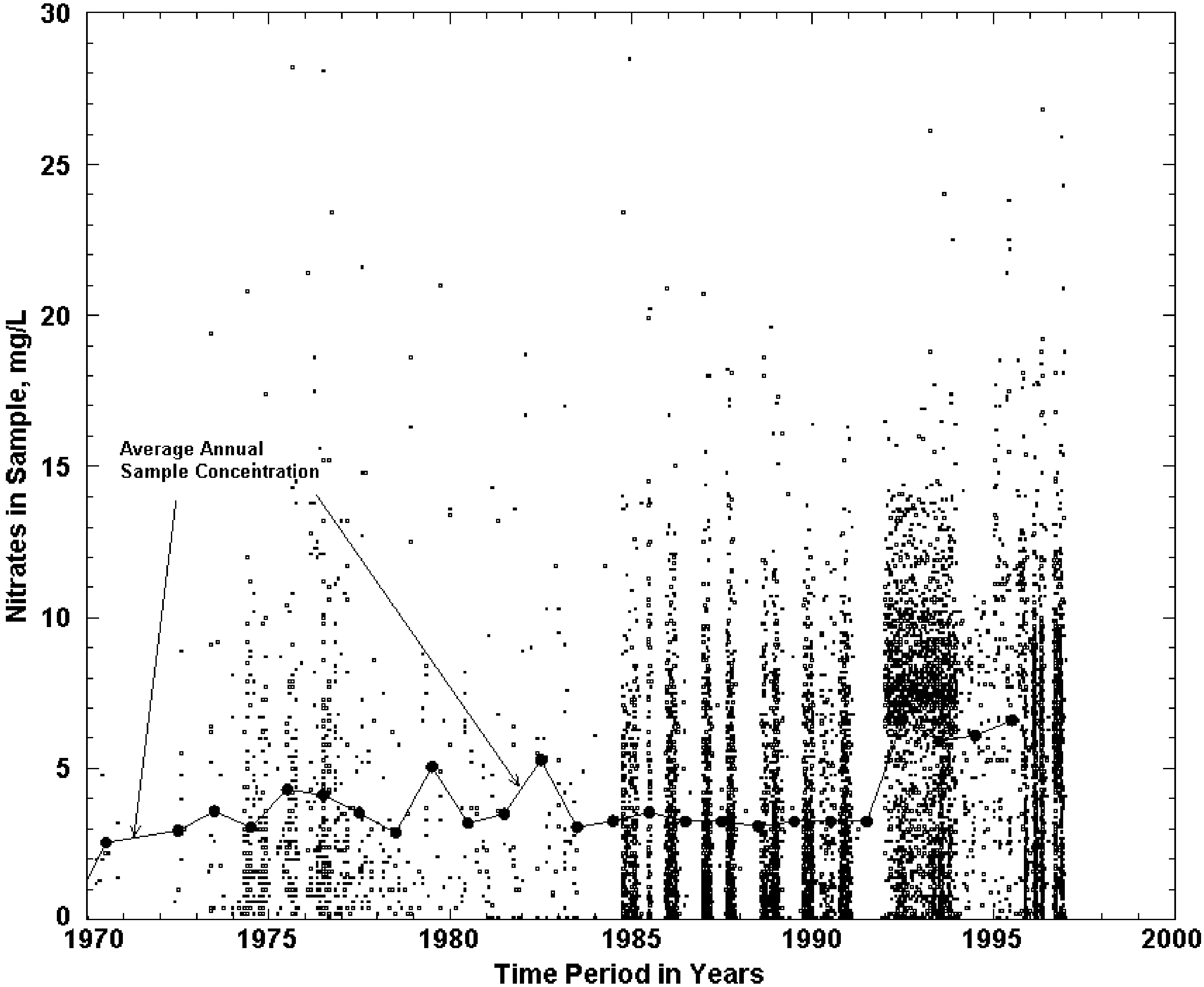
The analysis of historical community water system nitrate data is further complicated by the fact that sampling requirements have changed through time. Prior to 1993, samples were required from the distribution system. Since 1993, operators of community and nontransient systems have been required to monitor all groundwater entry points at least annually. However, if a sample shows a nitrate concentration of 5 mg/L or higher, then samples must be taken quarterly until samples for four consecutive quarters are shown to be below 8 mg/L. Quarterly monitoring is also required for water that is above the MCL at the entry point but is treated to meet standards. Changes in sampling requirements through time can be traced partially to Safe Drinking Water Act amendments. A final complication is that communities change their water systems through time, in some cases taking older, poorer wells out of production and bringing new wells on line.

The available sample record is generally much smaller prior to about 1984. New regulations issued In May 1977 required groundwater sources used as public water supplies to be analyzed for inorganic chemicals by July 1, 1979, and at 3-year intervals thereafter unless the maximum permissible level was approached. Much of the available HHSS record for the period prior to 1981 is found in the printed water quality data collections.

Figure 18 is a graph of data available in the electronic record only. Although it does not reflect all of the available data used in this report, it is still a useful indicator of the relative magnitude of data available before and after 1984. The increase in average sample concentration

Figure 18.—Available Electronic Records for Nitrates in Samples from Small Community and Domestic Water Supplies

Each sample point represents at least one well, point of entry, or a system sample for a time period



PLEASE NOTE THE FOLLOWING CAUTIONS:

- The remainder of this report uses the full data record including paper files and printed water quality data collections. However, this graph was included to provide a general indication of temporal distribution of data collection. The paper file generally fills the gaps shown later in the record.
- Average annual nitrate sample concentration line may often be somewhat higher than representative due to higher likelihood of systems with high nitrate being sampled. Note that the increase in the average annual sample concentration occurring after 1993 was very likely due to a change in sampling requirements from system samples to point of entry and quarterly monitoring for systems with high nitrate readings.

visible in 1993 was likely due to implementation of the previously mentioned regulations requiring point-of-entry data rather than system data as well as quarterly monitoring in some instances. The average annual sample concentration level depicted on the graph may also be somewhat inflated due to a higher likelihood that systems known to have high nitrate levels would be sampled.

LIMITATIONS OF NITRATE DATABASES USED IN THIS REPORT

All available HHSS files, including the paper-copy files, reports, and electronic files, were used in compiling almost all the aggregate nitrate sampling level data used in the report. However, the paper file was checked only for systems that had nitrate readings of 5 mg/L or higher. Data were collected separately for the 1961–80 and 1981–98 periods.

Several cautions should be considered when evaluating the nitrate-sampling data presented here:

1. Far more sample records are available from the period from 1984 through 1998 than for the period prior to 1984.

2. The analyses were compiled as one indicator of whether nitrate had *ever* been a significant concern to many small community water systems, not as an indicator of major ongoing problems.

3. The database includes both point-of-entry and distribution-system data.

4. These listings do not distinguish between systems that had only one high reading and those that had more than one.

5. A single nitrate sample in excess of 10 mg/L does not indicate that a community is out of compliance with state regulations. When a single high reading is reported, a second sample is taken, and the community is considered to be in compliance if the average of the two samples is below the MCL.

6. Some of the readings represented here came from backup or emergency wells.

7. This listing indicates only a past high reading or readings and does *not* imply ongoing nitrate problems. Only a very few systems are currently under administrative orders to address nitrate problems.

8. The earliest data used are from a January 1967 Department of Health report, which did not record the year samples were taken, though a handwritten annotation suggests some were taken as early as 1961. Sample collection dates prior to 1970 are generally uncertain.

At one point, the electronic file was used to compile graphs of individual communities' nitrate readings. However, those graphs are not presented or analyzed in this final report because it was found that each year's records in the electronic file reflected, on average, only about 60 percent of the communities that had reported readings that year (and this percentage is even lower for the period prior to 1984).

FINDINGS

Material from analysis of the HHSS databases is contained in figures 1 and 19. Each figure uses data from all available data sources, including electronic files, paper files, and printed water quality data collections. Figure 1 presents data for individual small cities and villages. It is classified according to whether the data are from before 1981 or after that time. As previously noted, far more sampling records are available for the period from 1984 through 1998. Figure 19 and corresponding table 6 include data only for the period after 1981 and only for small city and village systems. They include composite data by region for the number of community systems that have their highest nitrate sample readings in the three categories of less than 5, 5 to 10, and more than 10 mg/L. The number of sample readings in each of those categories in the full community system record is presented in table 7. For figure 19, each water supply system was assigned to a groundwater region (figure 2) based on the location of the nearest town. These were the same regions used by Gosselin et al. (1996, 1997).

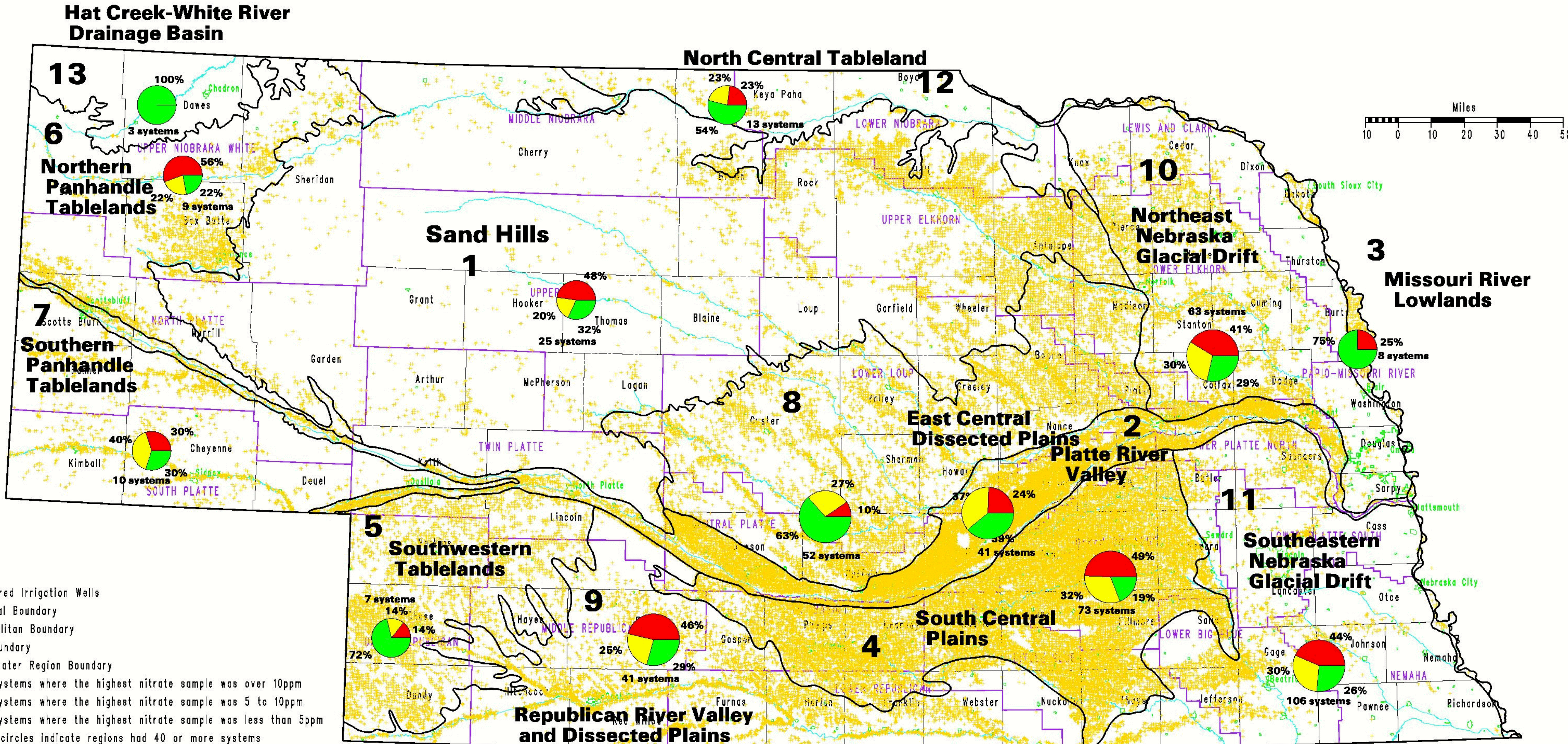
Table 6. Numbers of small city and village water systems in each groundwater region (GWR) that fall within three categories of maximum nitrate concentrations [1]

GWR	Total number of systems	Number of systems having maximum nitrate readings:		
		Less than 5 mg/L	5–10 mg/L	More than 10 mg/L
1	25	8 (32%)	5 (20%)	12 (48%)
2	41	16 (39%)	15 (37%)	10 (24%)
3	8	6 (75%)	0	2 (25%)
4	73	14 (19%)	23 (32%)	36 (49%)
5	7	5 (71%)	1 (14%)	1 (14%)
6	9	2 (22%)	2 (22%)	5 (56%)
7	10	3 (30%)	4 (40%)	3 (30%)
8	52	33 (63%)	14 (27%)	5 (10%)
9	41	12 (29%)	10 (24%)	19 (46%)
10	63	18 (29%)	19 (30%)	26 (41%)
11	106	28 (26%)	32 (30%)	46 (43%)
12	13	7 (54%)	3 (23%)	3 (23%)
13	3	3 (100%)	0	0
Total	451	155 (34%)	128 (28%)	168 (37%)

[1] Based on available records collected from the 1960s through 1998.

Figure 19

SMALL CITY AND VILLAGE WATER SYSTEMS
Maximum Single Nitrate Sample Readings By Groundwater Region
Available Record through 1998*



LEGEND

- Registered Irrigation Wells
- Municipal Boundary
- Metropolitan Boundary
- NRD Boundary
- Groundwater Region Boundary
- % of systems where the highest nitrate sample was over 10ppm
- % of systems where the highest nitrate sample was 5 to 10ppm
- % of systems where the highest nitrate sample was less than 5ppm
- Larger circles indicate regions had 40 or more systems
- Smaller circles indicate regions had 30 or fewer systems

Includes both distribution system and point of entry samples. Only one reading or one sample somewhere in the system will result in a system being included in the resulting highest reading category.
*Available record is far smaller prior to 1984. Earliest smaples used in analysis date to January 1967 Nebraska Department of Health report which does not provide sample years. The earliest samples noted in that report may date to as early 1961 for some communities.

NOTES:
Small systems are defined as those that serve less than 10,000 people. Includes both distribution system and point of entry samples.

SOURCES:
Nebraska Health and Human Services System paper and electronic files
Groundwater Regions from Center for Advanced Land Management Technologies - University of Nebraska-Lincoln Website
Map by Nebraska Natural Resources Commission
Nebraska Department of Health - Reports on Chemical Analyses/Public Drinking Water Supply/or Drinking Water Quality for 1967 1969 1973 1975 and 1984

Table 7. Small community water supply systems by system type and maximum nitrate reading, through 1998[1]

Maximum nitrate reading	ALL small community water systems (608 systems)		Small city and village water systems ONLY (451 systems)	
>10 mg/L	188	(31.1%)	168	(37.2%)
5–10 mg/L	160	(26.4%)	128	(28.4%)
<5 mg/L	257	(42.5%)	155	(34.4%)
Total	605		451	

[1] Earliest records used are from a January 1967 report that did not record the year of sample collection, but some samples may date to as early as 1961.

The analysis demonstrates and reinforces the importance of looking at the nitrate problem in the context of particular groundwater regions rather than statewide. The statewide analysis, for instance, showed that only 37 percent of the small city and village systems analyzed had a maximum nitrate reading greater than 10 mg/L. Within individual groundwater regions however, this result ranged from 56 to 0 percent. Similarly, systems that had maximum nitrate readings between 5 and 10 mg/L represented 28 percent statewide but ranged from 40 percent to 0 percent among the regions, and those with all readings less than 5 mg/L tallied 34 percent statewide but ranged from 100 to 19 percent among the regions. However, in some cases, these great variations may reflect the small number of systems within each region.

ALTERNATIVES FOR PUBLIC WATER SUPPLY SYSTEMS

SUMMARY OF ALTERNATIVES

Preventative Methods:

1. Wellhead Protection Programs
2. Groundwater Management Areas for Water Quality
3. Land Based Zoning/Easements/Purchase
4. Voluntary Landowner Action Through Education Programs
5. Voluntary Landowner Action Through Incentive Programs

Treatment Methods:

6. Reverse Osmosis
7. Nanofiltration
8. Ion Exchange
9. Electrodialysis
10. Denitrification Process/Reduction (Ex Situ)

11. Denitrification Process (In Situ)
12. Community Maintenance of Point-of-Use Water Treatment Systems

Substitute Water Supply:

13. New Well and Well Location
14. Same Well Location, Different Aquifer Layer
15. Blending Water from Multiple Wells
16. Storage and Blending
17. Substituting Surface Water for Groundwater
18. Conservation of Existing Supply

Other Distribution Systems:

19. Connecting to or Expanding Existing Rural Water Systems or Other Systems
20. New Rural or "Regional" Systems

Note: The alternatives presented are in addition to the option of continuing current operations and taking no new action. The viability and legality of that option vary with the circumstances of the individual system.

PREVENTATIVE METHODS

In most instances the least expensive option for addressing potential groundwater contamination is to prevent contamination from occurring in the first place. However, the effectiveness of actions designed to prevent or limit contamination is not always well established and can be difficult to gauge for a specific situation. Some options, such as land purchase, can be quite expensive. Others may involve regulation of a range of activities. However, the regulations and costs must be weighed against potential long-term contamination of supply as well as long-term expenditures on water facilities.

The first two alternatives listed as preventative methods are programs that combine a number of approaches. The remaining alternatives are more specific items available to communities or areas.

1. Wellhead Protection Programs.—The Nebraska Wellhead Protection (WHP) Program is administered by DEQ and is intended to prevent groundwater pollution from entering public water supply wells and making them unusable. Wellhead protection activities may include:

1. Analysis of groundwater field data
2. Delineation of Wellhead Protection Areas (WHPAs)
3. Education of economic development entities (such as banks) about WHP
4. Contaminant source inventories (and training workers for the inventory)
5. Supplementary water testing in existing wells
6. Hydrogeologic field investigations
7. Siting of new wells

8. Contaminant source management
9. Zoning WHPAs to protect them from contaminant source encroachment
10. Purchase of land or certain land rights
11. Relocation of water supply wells or potential contaminant sources
12. Legal defense of WHPA zoning
13. Compensation for condemned property or other property rights.
14. Programs of the Nebraska Rural Water Association

Maps showing potential contaminant time of travel are being completed for all remaining Nebraska communities as part of the Source Water Assessment Program. Only 15 or 16 communities statewide were known to have conducted a contaminant source inventory as of early 1998; however, communities are not required to notify DEQ of either a contaminant source inventory or a wellhead protection area. DEQ can provide information (including source water assessment for the community and a guidebook on conducting a contaminant source inventory) and some technical assistance to communities wishing to conduct wellhead protection activities. The source water assessment program aims to identify as many contaminant sources as possible within each delineated area, to determine the susceptibility of the public water systems in the area to the contaminants. Some natural resources districts are also a source of technical assistance. A contaminant source inventory can often be completed at little or no cost to the community. It can be a public service project for a local 4-H club, scout troop, school class, or adult group.

2. Groundwater Management Areas for Water Quality.—Natural resources districts or DEQ may establish groundwater management areas for protection of water quality in areas where non-point-source contamination of groundwater is a problem. The administering agency (to date only NRDs, although DEQ is also a possibility) can require one or more of the following measures. Most of the measures are most commonly applied to agricultural production and irrigation. Communities can contact their local natural resources district about their interest in management area activities.

1. Groundwater allocation/rotation
2. Well spacing
3. Installation of Water Meters
4. Reduction of Irrigated Acres
5. Best management practices
6. Water/soil analyses
7. Educational programs
8. Water quality monitoring
9. Other reasonable requirements

3. Land-Based Zoning/Easements/Purchase.—Local zoning, subdivision, building code and other authorities and ordinances can be used to protect public health. Villages and cities of the second class have 1 mile jurisdiction beyond their corporate limits. Purchase of land or easements is another option, which allows a high degree of control over activities that may threaten the water supply. Such purchases can be expensive, though, and any municipal purchase of land would remove that land from the local tax base. However, the land can in turn be rented back to the farm operator for income.

4. Voluntary Landowner Action Through Education Programs.—Landowner education programs are available from a number of sources and can be incorporated into a community's effort at addressing potential contamination problems. Natural resources districts have groundwater management plans that incorporate educational components, and educational efforts generally receive a special emphasis in groundwater management areas. The University of Nebraska Cooperative Extension Service (http://www.ianr.unl.edu/ianr/Coopext/Coopext.htm) is a major source of information and assistance at both the state and local level and is involved in a number of demonstration programs for agricultural and other landowners. Communities can use a wellhead protection program as a vehicle for promoting landowner education. The Groundwater Guardian Program (a national program of a Nebraska-based organization, the Groundwater Foundation) also can provide an educational component for communities.

The types of actions these programs will need to encourage vary with the problem area, but they generally include agricultural best management practices and irrigation management. The programs, especially in wellhead protection areas, may also include residential and small-business-related actions.

5. Voluntary Landowner Action Through Incentive Programs.—Although communities themselves may not be in a financial position to offer incentives to landowners whose actions may influence the water quality in their municipal wells, there are a number of programs that do provide such incentives. Communities can help make landowners aware of these possibilities. Some of the more important sources of incentives for landowners are listed below. (Contact information for the sponsoring agencies is listed in attachment C.)

The Conservation Reserve Program (administered by the Farm Service Agency of the U.S. Department of Agriculture; includes special provisions allowing higher cost share for lands in a wellhead protection area).

The Nebraska Soil and Water Conservation Fund (Nebraska Natural Resources Commission; funding to landowners is administered by local Natural Resources Districts)

Natural Resources Conservation Service

Local Natural Resources District cost-share programs (contact the local Natural Resources District)

TREATMENT METHODS

6. Reverse Osmosis.—Reverse osmosis forces water through a membrane, which causes it to leave most dissolved chemicals behind on the membrane. It is generally efficient enough to remove about 90% of the dissolved chemical constituents, and it works on all chemicals. The operator can then dispose of the material remaining behind, sometimes to a sanitary sewer. Creighton and Elmwood are the two Nebraska small community systems currently using this process. The advantages of reverse osmosis include the fact that it works across the chemical spectrum and that it removes such a high percentage of contaminants. Its major disadvantage is usually cost, especially for small systems.

7. Nanofiltration.—Nanofiltration is a form of reverse osmosis. The membranes used in nanofiltration have larger openings than conventional reverse-osmosis membranes, so less pressure is required to push water through them. This difference makes nanofiltration plants cheaper to operate, which has been an inducement to use nanofiltration in commercial nitrate treatment plants. A disadvantage is that the larger membrane size reduces the percentage of chemicals removed.

8. Ion Exchange.—Ion exchange treatment does not work upon as large an array of chemicals as reverse osmosis but is generally less expensive to operate. In the ion exchange process, nitrate-contaminated water passes through a bed of small plastic beads laden with chloride. The bed exchanges chloride ions for nitrate ions until it is saturated with nitrate. It is then exchanged for a second bed and is cleaned for reuse. Small Nebraska systems currently using this process are Adams, Hardy, Page, and a mobile home court in the Columbus area.

9. Electrodialysis.—Electrodialysis treatment plants separate nitrate from water using semipermeable membranes like those used in reverse osmosis. However, electrodialysis plants also have a positively charged electrode located on the upstream side of the membranes. Most of the negatively charged nitrate ions are attracted to the electrode and will cling to it. Any that get past the electrode are ultimately removed by the membrane. These membranes are like the ones used in nanofiltration. Hence, they have openings larger than those of typical reverse-osmosis membranes, generally making the electrodialysis treatment plants cheaper to operate.

10. Denitrification Process/Reduction (Ex Situ).— Nonpathogenic bacteria can be used to denitrify water in a treatment system. The bacteria inhale nitrates and exhale inert carbon dioxide and nitrogen gases. At least one low-cost system using this process has been developed specifically for small communities. In that system, vinegar is added to the water before it enters the treatment reactors, and the bacteria simultaneously consume the vinegar and the nitrates. The water is pumped through filters to remove the bacteria, and the waste products can be flushed to the municipal sewage system.

11. Denitrification Process (In Situ).—There has been research on the effectiveness of injecting a carbon source, such as ethanol, into the aquifer in an effort to cause denitrifying bacteria to function in the area around a pumping well. This can be done via a “daisy injection system,” in which injection wells are placed in a circle around an extraction well. There has been some success with this approach at the research level. To date no commercial application of this treatment method is noted in the literature.

12. Community Maintenance of Point-of-Use Water Treatment Systems.—Point-of-use water treatment with community maintenance is an option sometimes considered. One community experiencing nitrate-related problems, Bruning, recently examined this option. The chairperson of Bruning's village board stated that the treatment systems under consideration would probably have cost around $400 per household for drinking water only. Annual maintenance would probably have cost in the range of $65 to $90, and testing would probably have cost about $22 per household annually. A significant problem would be finding someone to do the maintenance if only one community were involved. Also, in a few instances, customers could be exposed to high levels of nitrate from a worn or defective device, especially if maintenance or testing were inadequate. The public water system would still be responsible for water quality. Individual costs can run higher than noted above, into the $500 to $1,500 range.

SUBSTITUTE WATER SUPPLY

13. New Well and Well Location.—The most common approach used by Nebraska's small communities to solve a persistent problem with high nitrates in a well has been to drill a new well. Establishing a new well location can involve costs for drilling and for a transmission line. As this study has shown (see "Data Analysis" section, above), some communities have achieved long-term success through this method, but many others have invested in new wells, only to see nitrate concentrations return to unacceptable levels within a few years. Communities should be strongly encouraged to consider wellhead protection options before nitrate levels reach the higher levels requiring new wells or other options.

14. Same Well Location, Different Aquifer Layer.—Sometimes an existing well can be deepened enough to reach an uncontaminated aquifer layer, separated from the previously used layer by an impermeable zone. Deepening an existing well or adding a new, deeper well a few feet away can avoid costs of a new transmission line. Deepening an existing well also avoids some of the costs of well construction. However, avoiding the spread of contamination between aquifers can be a problem at some locations with this alternative, depending upon geologic conditions.

15. Blending Water From Multiple Wells.—Most Nebraska water supplies involve multiple wells, usually at least one primary well and a backup. If a community has several wells and one develops high nitrate levels, a solution can be to blend its water with water from other wells before it reaches the consumer, thus delivering a product with nitrate below the MCL. Once put together in the same reach of pipe, turbulence within the pipe will result in blending. However, some communities have multiple wells in different locations. In many instances those wells deliver directly to the consumer, without being blended with water from other wells. In those instances some rerouting of transmission lines in the system may be an alternative.

16. Storage and Blending.—In some instances a community may have a backup well that is high in nitrate. When a major well is temporarily out of service, water from the backup well can be blended with water held in a storage facility to bring nitrate readings down to acceptable levels. Thus, additions to storage are sometimes an alternative.

17. Substituting Surface Water For Groundwater.—Groundwater accounted for more than 81% of publicly supplied water used in Nebraska in 1995. Almost all the use of publicly supplied surface water was in the Omaha region, though a small amount was used in Knox County and at Crawford. The availability of good quality groundwater in most areas, the increased treatment costs associated with surface water, and the variability of surface water quantity in many areas have combined to help limit surface water use for public supplies. However, groundwater availability is the most variable in the eastern quarter of Nebraska, an area that has relatively more surface water and is bordered by the Missouri River. In some future instances, surface water could conceivably provide an option for some communities. However, the high costs associated with treatment would likely make this only a last resort.

18. Conservation of Existing Supply.—Conservation of existing supply can allow a community to avoid the need to overuse a high-nitrate well in its system. It can therefore support any blending occurring by keeping nitrate at acceptable levels. In some respects, conservation of the existing supply is also a preventative method that can help protect groundwater beneath a community by discouraging overuse of water by customers and subsequent leaching to the aquifer.

Conservation methods can involve both the water distribution system itself and the practices of the consumer. Repairing leaks in the distribution system is one potential source of savings. Metering and the community water system rate structure can also help induce customers to conserve. A variety of physical changes can also result in conservation by community system customers, including: Toilet flushing control, showering control, laundry and cleaning controls, plumbing maintenance, dual or recycle systems, lawn irrigation scheduling, and landscaping practices.

OTHER DISTRIBUTION SYSTEMS

19. Connecting to or Expanding Existing Rural Water Systems or Other Systems.— As of January 1998**,** Nebraska had 23 rural water systems serving about 1.38% of the state's people and about 7 % of the total area of the state. In early 1998, an additional system was added. Most of those systems are in the eastern part of the state. Connecting to them is a viable option for communities in some areas. For instance, in 1992 the Village of Obert, which had been experiencing a nitrate problem, connected to the Cedar-Knox Rural Water District. Another option may be connection to existing urban or small community systems, especially any that have excess capacity. In each instance, connection will also depend upon the treatment capacity and distribution system of the existing systems. In general, the costs of transmission lines and other distribution costs are fairly high in rural/regional systems, and they are most likely to be located in areas where good quality groundwater is scarce. Rates and connection costs to consumers are also likely to be high in relation to the average community water system. An abundance of groundwater and low population density in much of the central and western portion of the state has probably helped limit development of rural/regional water systems in Nebraska. However, such systems are far more common in parts of the Eastern United States.

20. New Rural or "Regional" Systems.—Creation of a new rural or "regional" water system may depend in part upon both the level of need and the financial incentives to create such a system Since 1972, new rural water systems have been formed only as improvement districts within natural resources districts. As of early 1998, natural resources districts operated eight domestic rural water systems and were in the process of adding another.

ALTERNATIVES FOR SELF-SUPPLIED RURAL DOMESTIC WATER USERS

SUMMARY OF ALTERNATIVES

1. Preventative Methods
2. Point-of-Use Treatment
3. Deepening Well/Well Repair
4. New Well
5. Connection to an Existing Water System
6. Bottled Water
7. Well Operation/Conservation/Storage/Blending and Co-Use
8. Well Testing
9. Ceasing Use of Well
10. Continued Use of Well Despite High Nitrate Levels

DESCRIPTION OF ALTERNATIVES

In 1995, about 21% of Nebraskans received their water from private wells. Well characteristics, hydrogeology, site characteristics, and distance to a nitrate source are general factors that influence nitrate levels in those wells. Generally, because of cost constraints, private well owners have fewer alternatives for addressing water quality problems than are available to public systems. What follows is only a brief description of alternatives for self-supplied domestic water users.

1. Preventative Methods.—Private well owners have little control over land uses on surrounding properties but can control their own land-use practices. Proper septic tank maintenance and control of land uses around the wellhead can minimize risks. Minimizing use of potential contaminants in the immediate vicinity of the well can reduce the opportunities for spills or accidents. Abandoned wells can provide a conduit for contamination and should be properly closed. Barnyards have sometimes been noted as a source of contaminants, including nitrate. Programs such as Farm*A*Syst (a University of Nebraska Cooperative Extension program) can provide help in addressing farmstead water quality problems.

2. Point-of-Use Treatment.—If properly maintained, point-of-use systems can provide an alternative for rural households with limited options due to high nitrate levels in a well. Ensuring proper maintenance can be a significant problem. Point-of-use systems for drinking water include those that use distillation, reverse osmosis, or ion exchange. When examined as an option for one small Nebraska community, the equipment estimate was $400. Annual costs per household were expected to be about $65 to $90 for maintenance and $22 for testing. Costs can run higher than this amount, however, into the $500 to $1,500 range.

3. Deepening Existing Well/Well Repair.—Sometimes a shallow well may provide water with high nitrate levels that are not present in a deeper level of an aquifer, especially if that deeper level is separated by an impervious layer. In those cases, deepening the existing well may be less expensive than siting and drilling a new well. Care must be taken, though, to avoid providing a conduit for contaminants into the deeper portion of the aquifer. In a few other cases, original construction methods of an old well may allow the infiltration of nitrate and other contaminants into the well. In some of these instances, repair or modification of the well can slow or prevent the infiltration of contaminants.

4. New Well.—If well deepening or repair is not an option, the problem may be resolved by installing a new domestic well, pump, and piping, possibly at a different site or into a different layer of the aquifer. This typically costs in the range or $3,000 to $4,000, although it will vary with individual circumstances. New wells are subject to state well construction regulations.

5. Connection to an Existing Water System.—Some private wells are close to existing rural water district water lines or community water lines. In those cases, connecting to that existing system can be an economical option for addressing nitrate-related problems.

6. Bottled Water.—An estimate prepared for this report indicates that at 27 cents per gallon for water and 1 gallon per person per day, it would cost just over $8.00 per person per month to use bottled drinking water. This estimate is based on having consumers refill their jugs at a discount grocery store, assumes no cost for trips to the store, and assumes that a separate supply is still available for non-drinking-water uses. Although this cost is not prohibitive, many consumers would find the inconvenience to be a major drawback to continuous use of bottled water. Bottled water can also be used on a discontinuous basis. Pregnant women and infants are most at risk from high-nitrate water, and the short-term use of bottled water may be a means to ensure that this segment of the population always uses water with nitrate levels below 10 mg/L.

7. Well Operation, Conservation, Storage, Blending, and Co-Use.—Because the cone of depression around a well can draw in contaminants, some well owners find that their water quality is poorest during times of heaviest use. In some cases, lowering the rate of use or storing water during high-water-table periods for later use can have the effect of lowering nitrate levels consumed. The stored water may be consumed directly or may be blended with lower quality well water to keep nitrate levels within acceptable bounds. Similarly, using bottled drinking water during periods of high domestic well use for other purposes may provide high-quality water during what would otherwise be a period of low quality water and conserve water, thus marginally lessening the cone of depression that is drawing in poorer quality water. Storage and conservation are ways to address problems of wells that can draw in high nitrate water under certain aquifer conditions.

8. Well Testing.—In some respects this alternative does not directly address the problem of a water source with high nitrate levels. However, it is an option that helps identify a problem and its extent. Some commercial mortgage lenders require that private wells be tested as a condition of loan approval, and some Federal agencies require testing as a prerequisite for providing mortgage insurance. Inspection of new or existing private wells is not required. There is no state or Federal requirement that private wells be tested or that they meet water quality standards.

9. Ceasing Use of Well.—Occasionally a well problem may be one of the factors that contributes to an owner ceasing to use a building as a dwelling.

10. Continued Use of Well Despite High Nitrate Levels.—This is a legal option in Nebraska and one that has been adopted by a segment of the rural population. Some residents probably follow this option knowingly, whereas others are unaware of the level of nitrate in their water. Gosselin et al. (1996, 1997) sampled 1,808 private domestic wells in Nebraska found that approximately 19% of them exceeded the Federal MCL for nitrate nitrogen.

SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF ALTERNATIVES

Social and economic issues related to groundwater contamination can arise when the individuals or groups causing the pollution do not pay the full costs of the contamination. In the face of potential water supply contamination, communities have various options, as described in the previous section: they may try to prevent contamination in the first place, treat the existing contamination, obtain a substitute water supply, or connect to another distribution system.

IMPACTS OF PREVENTATIVE METHODS

Social and Economic Impacts

Financially, preventative action makes sense if the community can make a small investment now in an effort to avoid, or at least delay, a large investment. The down side is that preventative measures are risky, and cannot be guaranteed to work. Delaying a major investment can work in the community's favor in that it (1) allows time to accumulate capital (and interest), (2) allows time to find a source of grant money or some sort of cost share program, (3) avoids current expenditure, (4) may avoid expenditure altogether if water quality stabilizes or improves on its own, (5) may prevent the expenditure of money to meet current Federal standards, only to discover later that changed standards require additional action, and (6) may lessen political/social discord over potential actions.

In general, preventative methods rely primarily on a variety of land use changes. The first question is “What will the community have to pay in order to get those land use changes to take place?” Depending upon the approach taken there are many ways to estimate what those costs might be. If, for instance, the community decides on land purchase, the costs can be estimated using the information found in Johnson (1998) or in the most recent update to that report. Bruce Johnson, of the UNL Agricultural Economics Department, conducts an annual survey of farmland sales in the state. This information is reported based on type of land and grade for each of the eight Agricultural Statistics Districts in the state (table 8). If the community is interested in controlling the land use for a shorter time period, a rental rate may be more representative. Johnson also collects data on cash rental rates for farmland in dollars per acre per year. For example, if the farm normally rents as irrigated cropland, and the farmer agrees to rent it as pasture only, the rental income immediately drops from $130 per acre per year to $21 per acre per year (table 9).

A third means to estimate the compensation needed to get a farmer to change land use on a certain area of cropland is to calculate the decrease in profit to that operator for making the change. For instance, based on 1996 crop production budgets, a farmer producing irrigated corn in Hall County who agrees to produce dryland soybeans instead would give up profits of approximately $196 per acre per year (table 10). If the community wants to assure that irrigated corn is not produced, it will have to pay the farmer at least the value of the lost profit each year, for however many years it wants to control the land use.

The range of potential costs to influence land use for two crop reporting districts in central Nebraska is shown in tables 10 and 11. Since the most important areas of land to control are those in close proximity to a well, some landowners might take advantage of the situation and hold out for more money. On the other hand, altruistic landowners, concerned about the public water supply, may be willing to accept less than the actual loss of income caused by the land-use change. The numbers in tables 10 and 11 are only baseline values of prices per acre. Each individual site may end up with a different cost given other factors of consideration.

The Lower Platte South NRD in southeastern Nebraska has a very active wellhead protection area (WHPA) program at this time. In this area, WHPAs have ranged from 80 acres to 1,280 acres. The average size is 480 acres. Thus the cost per acre ranges presented in table 11 may need to be multiplied by anywhere from 80 to 1,280 times. As of 1998, most of the WHPA land use changes have been the result of education and voluntary actions.

Two Nebraska communities that have purchased land around their wellheads and now rent it out are Columbus and Nebraska City. Under this arrangement, the use of the land can be restricted to practices or uses that do not threaten the community water supply. A portion of the Drinking Water State Revolving Fund may be used for low-interest loans to purchase easements or fee title to land around wellheads. No other Nebraska communities are known to have undertaken major land purchases or leasing options in order to protect their wells.

Land costs are not the only costs that may be incurred in setting up a WHPA. However, other costs can vary widely. Expenses for the initial 2-year startup or implementation period are

Table 8. Average Reported Value Per Acre of Nebraska Farmland for Different Types and Grade of Land by Agricultural Statistics District, February 1, 1998.[a]

[From Johnson (1998, table 3)]

Type of Land and Grade	Agricultural Statistics District							
	Northwest	North	Northeast	Central	East	Southwest	South	Southeast
	(dollars per acre)							
Dryland Cropland (No Irrigation Potential)								
Average	385	390	982	631	1,477	457	753	956
High Grade	450	475	1,275	735	1,700	545	870	1,315
Low Grade	275	275	710	470	1,050	340	520	700
Dryland Cropland (Irrigation Potential)								
Average	482	510	1,219	986	1,810	578	1,216	1,250
High Grade	555	685	1,350	1,210	2,010	650	1,375	1,540
Low Grade	380	415	935	695	1,340	430	905	1,035
Grazing Land (Tillable)								
Average	153	265	550	461	741	227	467	575
High Grade	170	360	680	585	865	280	555	725
Low Grade	120	215	480	395	555	200	340	465
Grazing Land (Nontillable)								
Average	128	199	395	366	516	189	337	473
High Grade	145	245	500	410	630	215	385	570
Low Grade	100	140	365	280	380	150	250	375
Hayland								
Average	315	345	517	472	640	336	437	497
High Grade	355	495	630	565	750	465	500	580
Low Grade	250	280	450	365	495	290	325	380
Gravity Irrigated Cropland								
Average	925	1,150	1,575	1,972	2,340	1,200	2,042	1,936
High Grade	1,095	1,430	1,835	2,200	2,605	1,365	2,225	2,150
Low Grade	650	900	1,190	1,445	1,790	870	1,385	1,340
Center Pivot Irrigated Cropland [b]								
Average	829	1,020	1,583	1,698	2,332	1,139	1,863	1,907
High Grade	915	1,200	1,845	1,880	2,595	1,260	2,035	2,185
Low Grade	570	800	1,240	1,225	1,750	780	1,340	1,485

[a] SOURCE: 1998 UNL Nebraska Farm Real Estate Market Developments Survey.
[b] Value of pivot not included in per acre value.

Table 9. Reported Cash Rental Rates for Various Types of Nebraska Farmland: 1998 Averages and Ranges by Agricultural Statistics District.[a]

[From Johnson (1998, table 8)]

Type of Rental Rate	Agricultural Statistics District							
	Northwest	North	Northeast	Central	East	Southwest	South	Southeast
	(dollars per acre)							
Dryland Cropland (No Irrigation Potential)								
Average	22	39	79	53	88	32	51	70
High	28	51	99	67	106	40	63	91
Low	17	32	61	40	71	23	38	53
Gravity Irrigated Cropland								
Average	91	105	116	129	136	103	133	128
High	114	130	135	147	160	120	152	149
Low	63	90	103	105	115	82	113	103
Center Pivot Irrigated Cropland								
Average	95	115	125	132	143	111	138	132
High	123	136	144	147	167	130	156	161
Low	68	89	106	107	124	90	118	107
Dryland Alfalfa								
Average	([b])	([b])	79	58	86	([b])	59	64
High	([b])	([b])	96	73	102	([b])	72	78
Low	([b])	([b])	62	44	69	([b])	46	48
Irrigated Alfalfa								
Average	([b])	([b])	118	112	124	([b])	([b])	([b])
High	([b])	([b])	137	134	142	([b])	([b])	([b])
Low	([b])	([b])	98	97	108	([b])	([b])	([b])
Other Hayland								
Average	([b])	([b])	48	43	50	([b])	([b])	([b])
High	([b])	([b])	58	51	62	([b])	([b])	([b])
Low	([b])	([b])	39	29	40	([b])	([b])	([b])
Pasture								
Average	8	12	31	22	30	12	21	25
High	10	16	38	27	41	16	26	36
Low	5	9	22	17	21	9	15	18
	Dollars per animal unit month [c]							
Average	18.10	23.70	21.00	23.40	23.60	23.40	22.20	21.70
High	22.70	28.60	25.10	28.25	26.80	27.20	27.60	26.35
Low	14.70	20.20	17.25	19.50	20.80	17.80	18.20	17.35

[a] SOURCE: Reporters' estimated cash rental rates (both averages and ranges) from the 1998 UNL Nebraska Farm Real Estate Market Developments Surveys.
[b] Insufficient number of reports.
[c] “Animal unit month” refers to sufficient forage capacity to sustain an animal unit (1,000-pound cow with calf at side or equivalent) for one month during the normal range season.

Table 10. Decreases in Net Income (Dollars per Acre) Resulting from Changes in Land Use—East-Central Crop Reporting District

[N.A., not applicable. Compiled by Nebraska Natural Resources Commission using current Nebraska crop budgets and prices]

Former Land Use	Net income	New Land Use: Rent – Pasture	Rent – Dry	Rent – Irrigated	Wheat – Dry	Soybeans – Dry	Corn – Dry	Grain Sorghum – Dry	Corn – Irrigated
Corn – Irrigated	436.63	407.36	351.63	294.63	278.48	198.03	133.53	23.93	0
Grain Sorghum - Dry	412.70	383.70	327.70	N.A.	254.55	174.10	109.22	0	
Corn – Dry	303.48	274.48	218.48	N.A.	145.33	64.88	0		
Soybeans – Dry	238.60	209.60	153.60	N.A.	80.45	0			
Wheat – Dry	158.15	129.15	73.15	N.A.	0				
Rent – Irrigated	142.00	113.00	57.00	0					
Rent – Dry	85.00	56.00	0						
Rent – Pasture	29.00	0							

Note purchase price per acre:

Irrigated cropland	$2,111
Dryland cropland	1,336
Pasture	468

Table 11. Decreases in Net Income (Dollars per Acre) Resulting from Changes in Land Use—Central Crop Reporting District

[N.A., not applicable. Up arrow (↑) indicates an increase in income. Compiled by Nebraska Natural Resources Commission using current Nebraska crop budgets and prices]

Former Land Use	Net income	New Land Use: Rent – Pasture	Rent – Dry	Rent – Irrigated	Wheat – Dry	Soybeans – Dry	Corn – Dry	Grain Sorghum – Dry	Corn – Irrigated
Corn – Irrigated	345.41	324.41	292.41	215.41	232.51	196.01	172.44	↑ 8.75	0
Grain Sorghum - Dry	354.16	333.16	301.16	N.A.	241.26	204.76	181.19	0	
Corn – Dry	172.97	151.97	119.97	N.A.	60.07	23.57	0		
Soybeans – Dry	149.40	128.40	96.40	N.A.	36.50	0			
Wheat – Dry	112.90	91.90	59.90	N.A.	0				
Rent – Irrigated	130.00	109.00	77.00	0					
Rent – Dry	53.00	32.00	0						
Rent – Pasture	21.00	0							

Note purchase price per acre:

Irrigated cropland	$1,507
Dryland cropland	588
Pasture	327

estimated at $3,000. This amount would cover staff and material costs for delineating the WHPA, doing a contaminant inventory, and posting signs. The cost of monitoring well construction can vary depending upon the number of wells chosen and their depth. Then the initial full-scale sampling to get baseline information could cost another $10,000. Testing costs about $250 to $300 each time a set of samples is run (although testing for nitrate only is in the range of $18 to $23). In areas where vadose zone or deep soil sampling is needed, the cost may be $500 per core. One community in Nebraska recently invested $63,000 in its WHPA. However, outside sources of funding have limited that community's actual contribution. A community's actual expense may be substantially less than the above amounts depending both upon physical conditions and the degree of community commitment to wellhead protection.

In addition to the price of the land and the WHPA startup costs, there are third-party economic impacts to consider:

1. Property taxes may be impacted. If the community purchases the land adjacent to the well, that property will come off the tax rolls entirely, thus decreasing tax revenue to local governmental units. If the landowner agrees to a permanent or semi-permanent change in land use, this will decrease the market value of that land. In that case, the owner would be able to ask for a reassessment of the property, probably decreasing the assessed value of the land, and thereby decreasing the taxes paid on that property. In general, then, local tax revenues will decline. This may increase the tax burden on the remaining landowners in the immediate area or cause cutbacks in public services.

2. Agricultural production may be impacted. Around some communities, only small areas of agricultural land may be needed for wellhead protection. In these cases there may not be a noticeable impact on production except that the original landowner may need to search for additional land elsewhere to farm in order to maintain the same level of farm income.

3. Adjacent landowners may be impacted both positively and negatively. For instance, a less intensive use of land may result in an increase in wildlife habitat. Increases in deer herd size may cause greater crop damage than previously experienced. On the other hand, the positive impacts on groundwater quality might outweigh any negative impacts for nearby landowners.

Voluntary landowner action programs are usually related to existing Federal and state-funded groundwater protection programs. This lowers the immediate cost to the community and spreads the cost out over a larger group of taxpayers. Because these programs are voluntary, they may only be partially effective. Many of the activities promoted by educational programs require farmers to invest both additional time and additional management effort. An example would be the advice to do more field scouting or soil testing to assure that chemicals are used only when economically necessary. The ultimate impact on profit to the farming operation cannot be forecast. Profits may increase for some operators and decrease for others. This is where the economic incentive programs help. The dollar payments received by farmers for participating in certain best management practices help to offset any increased costs or decrease in profits.

Environmental Impacts

It is generally easier and cheaper to prevent water contamination than it is to treat contaminated water. In the alternatives listed above, a change in land use, such as converting cropland to grassland, is commonly the method used to protect the water. Impacts to the environment are nearly always positive as sources of pollution are removed. Habitat diversity may also increase on land set aside to protect either surface water or groundwater. The size of the area affected and the exact nature of the changes undertaken may vary from one program to another.

Many measures used to protect water resources may also have benefits that prevent loss of topsoil into rivers. Measures that improve land cover may include tree planting, riparian zone plantings, and grassed waterways. All of these activities help reduce sedimentation and also provide natural habitat for wildlife. Additional habitat benefits can be gained by creating wetlands, and the wetlands may have the further effect of reducing nitrate levels in both surface water and groundwater. Arguably, though, some measures that decrease runoff to benefit surface water quality might result in some infiltration of contaminants to the local groundwater.

Most land-use changes that are undertaken to protect the environment are described as "best management practices." These actions protect soil, surface water, and groundwater with little or no negative effect to the environment.

Irrigation water management is a best management practice that can be especially relevant to groundwater nitrate levels. Careful management can reduce water usage to prevent runoff, leaching, and the excessive use of chemicals. Soil moisture may be monitored to update watering schedules to prevent overwatering. Flow meters may be added to determine the amount of water used, and chemigation can be used to efficiently apply nitrate to fields. However, farmers using chemigation must carefully maintain the equipment, since a breakdown could allow chemicals to flow back down into the well and contaminate the aquifer.

Scheduling irrigation and ceasing fall fertilization of crops are also practices that can be especially beneficial to groundwater.

IMPACTS OF TREATMENT METHODS

Social and Economic Impacts

The Bureau of Reclamation estimated construction costs for the four major treatment methods (appendix II). All construction cost estimates are for equipment and contingency costs only. Reclamation also prepared estimates of O&M costs for various situations. In general, the electrodialysis and ion-exchange processes are the lower cost options. Reverse osmosis and nanofiltration are more expensive to construct and operate. Other site-specific costs were not estimated due to the vast number of factors to be considered: water quality, potential water quality problems, need to purchase additional property to site the plant, etc. It is impossible to estimate the total cost of a system except on an individual site basis.

Total cost is not the only figure that a community will need to be concerned with when deciding on a treatment system. Because of the size of the investment, the financial capability of the community needs to be examined. As explained above, under “Legal/Institutional Factors,” financial assistance is available through a variety of programs, and these should also be considered. Changes in the population of the area are also important. An area that is gaining people will have a larger base of taxpayers to support the project. An area of declining population will only be putting an increasingly difficult burden on its taxpayers. A community with a newly installed treatment system may be looked upon favorably by industries hunting for a location to expand. Thus, the investment in treatment may actually contribute to population growth. A community also needs to consider what other infrastructure costs it may be facing in the future. Are there already bonds let, which need to be repaid? Are there street projects or wastewater treatment projects that are more pressing?

Environmental Impacts

The methods discussed are mainly used to treat water for public consumption. Methods of treatment such as reverse osmosis, nanofiltration, ion exchange, and electrodialysis produce a number of byproducts that need to be disposed of in a method accepted by local authority. These may include spent filters and waste products from pretreatment, and most produce a brine stream.

Water treated by reverse osmosis leaves behind brines, spent filters, membrane elements, and concentrated waste that is about 20% of the raw water. Treatment by nanofiltration is much the same as reverse osmosis and has similar byproducts, which must be disposed of properly.

Waste created during treatment by ion exchange may include concentrate from the regeneration cycle (made up of a highly concentrated nitrate solution), occasional solid waste (mostly broken resin beads included in the backwash during regeneration), and a brine stream. Byproducts may also include spent filters and backwash wastewater if used during treatment.

Treatment by electrodialysis creates highly concentrated reject flows and electrode cleaning flows. Approved disposal would also be needed for waste from pretreatment processes and spent materials.

Denitrification processes (both ex situ and in situ) are experimental methods of removing nitrate from water. Part of the waste problem associated with these methods includes removal of nonviable bacteria by filtering. If left in the treated water these “bugs” would decompose and foul the water. Also, during the treatment of nitrate, the microorganisms form nitrite. This is a suspected carcinogen and may get into the product stream if enough carbon has not been added to complete the treatment process.

The cost of disposing of byproducts left by water treatment, and the disposal method used, depend on the type of water treatment and amount of waste material produced. Nitrate-contaminated water from reverse osmosis may be discharged into a nearby stream if the amount of flowing water in the stream is sufficient to dilute the nitrate to an acceptable level. (No state or national standards have yet defined an "acceptable" level for nitrate in surface water, but it probably could be somewhat higher than the drinking water MCL.) The brine stream is generally discharged to the sewer system. The cost of disposal may also be highly variable. In the situation described above, the treatment plant operators would incur the cost of installing a pipeline to discharge the nitrate water into the stream. The amount of waste product also depends on the type of treatment and the level of contamination existing in the aquifer. In some cases only a portion of the water is treated; the treated water is then blended into water from other sources to lower the level of contaminants.

Treated water that is produced for public consumption generally has little impact on the environment. A positive impact would result if the treated water were pumped back into the aquifer, thereby diluting the contamination in the aquifer. However, "pump and treat" operations such as this are expensive, highly regulated, and not commonly used. Negative impacts on the environment could occur if nitrite, brine, or other concentrated byproducts of the water treatment were put back into the environment without further treatment. This material could pollute surface water and, if it got back into the aquifer, could continue to degrade a water supply that is already endangered.

IMPACTS OF SUBSTITUTE WATER SUPPLIES

Social and Economic Impacts

Finding substitute water supplies involves many of the same economic concerns as other alternatives already discussed. Costs for purchasing land or acquiring rights-of-way can be determined as described above in the Preventative Methods section. Repayment capacity issues will parallel those described in the Treatment section. Many of the alternatives presented as substitute water supplies still involve a high level of risk of failure. There is no guarantee that any new well brought on line will remain free of nitrate contamination. Any type of construction of water lines or new well sites will cause some level of street or road disruption.

Any substitution of surface water for groundwater would require large expenditures for installation, operation, and maintenance of a treatment system, as well as legal fees and a variety of licensing fees involved in obtaining a water right. Public hearings may be required. Then, even if a surface water right is granted, the supply may not be adequate in times of drought. Hence, the community may still be faced with the costs to maintain former equipment or supply lines. Even wells that are abandoned may pose a liability issue. Wells that are abandoned but not properly sealed can increase the chances of groundwater contamination and may also be a safety hazard. Overall, substitution of surface water for groundwater is likely to be, at best, an expensive last resort for most small communities.

Environmental Impacts

Once a community drills a well at a new location, it either abandons the older (contaminated) supply or blends it with water from the new supply. If water from the old well is blended with clean water, the decreased volume of water pumped may mean that the well draws from a smaller area of the aquifer and, hence, may produce water of somewhat better quality. On the other hand, if the source of contamination in the old water supply is not cleaned up or restricted, the problem may continue to worsen. Eventually it could even endanger the new drinking water supply. Old wells that are to be abandoned must be properly capped and sealed to prevent them from becoming an additional source of contamination to the aquifer.

Similarly, if the new supply is obtained from a deeper aquifer layer, either by deepening the present well or by drilling a new well through the contaminated aquifer, contaminants from the overlying layer can spread to the new, clean water supply if the well is not properly constructed.

The use of surface water in place of (or in addition to) groundwater may result in the loss of water for fish and wildlife and possibly the loss of riparian habitat. It will also require acquisition of a surface water right, which may be difficult in areas where waters are already fully appropriated. Municipal wells drilled near rivers also affect surface water, but water loss due to drawdown from the alluvial aquifer generally takes longer to affect the river than drawing water directly from the channel. Drawing water from aquifers near streams may sometimes require manipulation of the river, such as impoundment of surface water, to ensure adequate flows for use downstream or for fish and wildlife. In some areas of Nebraska acquisition of either a new surface water right or an induced recharge right is complicated by potential environmental commitments for endangered species protection and instream rights. Treatment of surface water is not only more expensive, but would most likely produce byproducts such as concentrated contaminants, brine, spent filters, and solid wastes, all of which would need to be disposed of properly to keep them from degrading the environment.

Conservation of the existing water supply can protect the aquifer with few or no negative impacts to the environment. It is often environmentally preferable to drilling a new well, for instance, which could cause contamination to the aquifer if protective measures are not taken. It is also environmentally preferable to building water treatment facilities, which do produce safe drinking water but also create a few limited waste materials that could further endanger the aquifer if not disposed of properly. Water that is consumptively used is not available for other uses with environmental benefits.

IMPACTS OF OTHER DISTRIBUTION SYSTEMS

Social and Economic Impacts

Attaching to an existing rural water system or developing a new rural water system entails construction and distribution costs similar to those of other alternatives. This alternative does help to spread out any costs to a larger group of water users. The down side is that the capacity of the original system may be exceeded sooner than expected and users may still find themselves short of good drinking water. Joining a nearby system also has the problem of moving the control of the system further away from the actual users. This may not be acceptable to a community.

Environmental Impacts

Creating a new rural or "regional" water system or connecting to or expanding existing water systems can result in land disturbance for laying new pipe, energy costs for increased pumping, and impacts to the aquifer from wells and pumping by the new or expanded system. In most cases these impacts will be minor if sufficient planning has taken place before installation or expansion of a system.

CONCLUSIONS

NITRATE CONDITIONS

The available data for Nebraska small city and village community water systems indicate that more than one-third of such systems have had no nitrate reading higher than 5 mg/L and, therefore, have no apparent drinking water problem due to nitrates. Roughly 28% of the community systems have had at least one reading in the range of 5–10 mg/L, and 37% have had a reading above the MCL of 10 mg/L. Many small city and village community water systems have experienced elevated nitrate levels at some time. At any one time, however, all but a very few systems are generally in compliance with standards, as systems that have had a violation take steps to come back into compliance.

This investigation has shown that many factors affect the potential for nitrate contamination to groundwater supplies for Nebraska's small communities. The local variability in these factors gives each community its own unique groundwater conditions. The more important factors include the depth to water table, the surface soil permeability, land use and slope, cropping patterns, and agricultural practices. Statewide analysis using the DRASTIC method relates the potential for nitrate contamination of groundwater based on various physical factors. (See figure 14.) These same factors must be understood to develop reliable management programs to prevent contamination or improve groundwater quality. Past studies have shown that intensive agricultural practices are likely to cause elevated levels of groundwater nitrate concentrations above the MCL of 10 mg/L. Compared to most states, Nebraska has large areas of permeable soils, croplands, irrigation, and fairly shallow water tables. Wherever two or more of these conditions overlap, there are likely to be continuing challenges in limiting nitrate levels in groundwater.

COMMUNITY RESPONSE TO NITRATE CONTAMINATION

Since 1981, Nebraska small cities, villages and rural water systems have built or are in the process of building 59 nitrate-contamination-related projects with a total estimated final construction cost of more than $24 million, according to data compiled for this report.

During 1996 and 1997 combined, nitrate-related projects of small cities and villages accounted for about 8.8% of total estimated final cost of Nebraska community water system infrastructure projects applications. In 1995, a U.S. Environmental Protection Agency report (EPA, 1997) estimated that Nebraska's 20-year need for drinking-water infrastructure was almost $953 million, and that small systems serving fewer than 3,000 people accounted for $472.2 million of that need. That report also estimated Drinking Water Act needs related to nitrate at only $8.4 million and total Safe Drinking Water Act needs at more than $184 million. Given the spending levels indicated in this report, it appears the $8.4 million 20-year need ascribed to nitrate may be an underestimate.

Since the data indicate that small community water supplies and domestic wells are strongly affected by local conditions within the wellhead area, the study team reviewed a list of communities that have made changes to their systems since 1981. The study team evaluated the effectiveness of these changes by reviewing plotted nitrate data from the electronic files. This evaluation identified six communities that successfully eliminated nitrate problems simply by adding new wells, but it found eight others that tried the same approach, only to see nitrate levels rebound within a few years. Communities that added treatment capability have maintained acceptably low nitrate concentrations ever since. A small community considering changing its water supply should study the experiences of these other communities—especially those that seem to have similar geologic, hydrologic, and agricultural settings—before deciding on a course of action. Among the 59 Nebraska communities that made public water system infrastructure improvements in response to nitrate, drilling a new well appeared to be the single most common response.

ALTERNATIVES FOR SMALL COMMUNITIES

Nebraska has a myriad of geologic and water quality conditions. Similarly Nebraska's small towns have many different types of water system infrastructure with varying degrees of interconnection. Given those conditions, one should not expect a single solution to nitrate contamination to fit all communities. Prevention has major cost and environmental advantages but is slow or ineffective for addressing problems that have already reached a critical stage. Drilling a new well is the most common approach used by communities. However, if the geologic conditions are not right or if the remaining wells in a system continue to worsen, the problem can return. Treatment systems can solve the problem but are often very expensive for small communities, have high maintenance costs, and can require a higher level of skills for their upkeep. Only a few of Nebraska's small communities have installed treatment systems for the primary purpose of addressing nitrate problems. Some of the alternatives that can be considered by small communities follow. The alternatives presented are in addition to the option of continuing current operations and taking no new action. The viability and legality of that option vary with the circumstances of the individual system.

Preventative Methods:

1. Wellhead Protection Programs
2. Groundwater Management Areas for Water Quality
3. Land Based Zoning/Easements/Purchase
4. Voluntary Landowner Action Through Education Programs
5. Voluntary Landowner Action Through Incentive Programs

Treatment Methods:

6. Reverse Osmosis
7. Nanofiltration
8. Ion Exchange
9. Electrodialysis
10. Denitrification Process/Reduction (Ex Situ)
11. Denitrification Process (In Situ)
12. Community Maintenance of Point-of-Use Water Treatment Systems

Substitute Water Supply:

13. New Well and Well Location
14. Same Well Location, Different Aquifer Layer
15. Blending Water from Multiple Wells
16. Storage and Blending
17. Substituting Surface Water for Groundwater
18. Conservation of Existing Supply

Other Distribution Systems:

19. Connecting to or Expanding Existing Rural Water Systems or Other Systems
20. New Rural or "Regional" Systems

POTENTIAL COURSES OF ACTION — GENERAL

1. Keep plots or graphs of nitrate concentration over time for each point of entry into each water system. This may assist the community in detecting long-term trends and instituting preventative programs. Both the community and the HHSS Department of Regulation and Licensure could keep the plots.

2. Implement wellhead protection. Communities that have nitrate concentrations above 5 mg/L would make full use of the DEQ's Source Water Assessment Program Information by (1) setting up wellhead protection areas for their well or well field, (2) implementing best management practices, and (3) making full use of DEQs Source Water Assessment Program.

3. Provide incentives for adoption of groundwater-quality-oriented BMPs in wellhead protection areas. This could be done through a state-level program that would provide incentive funds and administrative assistance for wellhead area BMPs when a community requests assistance.

4. Create additional "circuit-rider" programs for providing assistance to communities. Such personnel could, for instance, assist in setting up wellhead protection programs. Circuit riders to assist with monitoring and with water system operation and maintenance should also be considered. NDEQ, the NRDs, NRWA, and HHSS are potential partners.

5. Fund an incentive program to install monitoring wells upgradient of the source wells for community water supplies, at or beyond the 20-year time-of-travel limit. Such a program could be administered by HHSS and funded through the Environmental Trust or other sources.

6. Enhance programs to inform rural well owners of testing needs and potential risks. This could build on existing programs of the Cooperative Extension Service and the Natural Resources Districts.

7. Consider incentives for upgrading or replacing dug wells and possibly other domestic wells currently in use that do not meet an identified standard. Also make sure that programs are adequately funded to address the resulting closing and capping of those wells.

8. Inform local health care providers of community nitrate levels in those communities that have experienced readings above 8 mg/L.

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